6

WEATHER FORECASTING: WHAT YOU NEED TO KNOW

Chapter Highlights:

- ✓ Discover weather tools- radar, computer models, upper air soundings, satellites.
- ✓ Learn how forecasts are made.
- ✓ Climate demystified.
- ✓ Web resources.

The first part of this chapter looks at the decision making process that a meteorologist uses to produce a forecast. In addition, we will give a brief overview of the various weather tools that are currently in use. The goal of this chapter is to show the strengths and weaknesses of the forecast process, in so doing it will give you some appreciation of what is involved. Secondly, it will teach you how to evaluate the forecast products that you might use. With the accessibility of weather related products on the Internet, some readers are already starting to look at model output, satellite imagery and surface observations before they venture into the mountains. Frankly this is the way it should be done, mountain travelers taking responsibility for their own comfort and safety. The caveat to this however is that just because a person regularly looks at weather maps, does not mean that they know how to forecast the weather with any skill. Here is an analogy we like to use: not everyone who carries a ice tool knows how to use it properly, let alone climb a waterfall. When it comes to weather forecasting, it takes a number of years of experience with many failures and successes along the way, in order to become proficient at it. Even then, weather forecasting is far from an exact science.

Tools of the Trade

In the following section an overview of five different forecasting tools will be presented These tools range from low-tech to high-tech, some of which are only a few mouse clicks away from your own monitor.

<u>Surface Observations</u>

Surface observations are the 'tried and tested' tool of forecasting. You may be asking why would a forecaster want to spend time looking at current conditions when they should be concerned with what is going to occur in the future? The answer is pretty basic, what occurs upstream frequently moves downstream. For example, if observations indicate that it is snowing along a line from Salt Lake City to Flagstaff, then there is a reasonably good chance that this same storm will shortly move into western Colorado as well. Conversely, if it is snowing in western Colorado, it does not mean that it is going to snow in Salt Lake City, because most synoptic-scale storms move from west-to-east. We can sum this up by stating: "If you want to know what will happen in the future, you need to understand what is happening in the present." In other words, weather that is occurring at the present time <u>may</u> continue for some time to come (persistence). It's the job of the forecaster to figure that out.

Surface weather observing stations routinely measure temperature, wind speed, wind direction, dew point temperature (from which RH is calculated), horizontal visibility, cloud heights as well as sky coverage (percent of sky covered by clouds), and precipitation. Surface weather maps, which are constructed from hundreds of surface observations, are an important forecast tool because they indicate the position of highs and lows as well as frontal boundaries. Virtually all primary weather stations in the U.S. use fully automated surface observing systems (called ASOS). These weather stations take sensor readings every few seconds, however the 'official' observing time is ten minutes before the hour. This means that the values that are displayed for a particular observation, may or may not be representative of what occurred thirty or forty minutes earlier. Consider how ASOS calculates wind speeds for example; the wind sensor measures the speed of the wind every second, and then computes a 5-second average. The wind speed displayed at the official observing time is a two-minute average of the 24 previous 5-second averages. For example, if the time of observation is 10:50 AM, then the displayed wind speed is an average from 10:48 AM to 10:50 AM. A wind gust on the other hand is the single highest 5 second average that occurred during the ten minute period prior to the observation. The peak wind gust is the highest 5-second value that occurred during the last hour. If weather conditions are rapidly changing, ASOS stations are programmed to take extra observations in addition to those that are routinely taken at ten minutes before the hour.

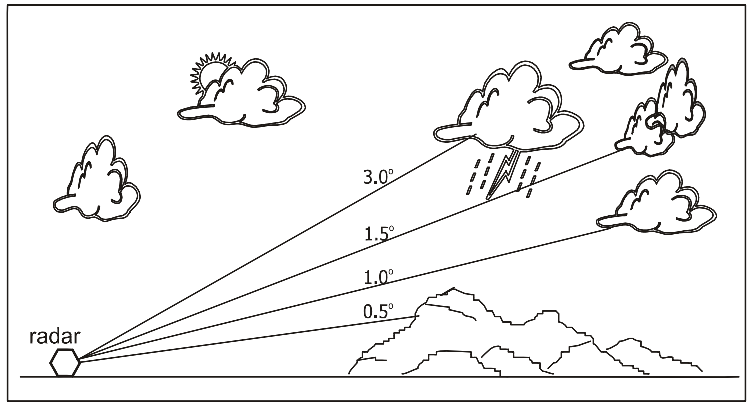

Figure 6.1- Radar elevation scans (exaggerated). The radar rotates through 360° in about six minutes. Notice how the lowest scan is blocked by the mountains.

Air temperature is calculated using the average temperature in the 5 minute period preceding the time of observation. Precipitation data is based on the amount that has fallen into the rain gage over the previous hour, unless otherwise noted. Be aware that most NWS forecast offices report a midnight-to-midnight precipitation total in their routine weather forecast products. If precipitation occurred in the form of snow, then a total depth and snow water equivalent (the amount of water resulting from melting a sample of snow) are reported as well.

There are thousands of secondary weather observation sites (cooperative observers) around the USA which use human observers exclusively. The types of data collected by the cooperative observers varies from one site to another, however they typically record: daily maximum and minimum temperatures, temperature at the time of observation, and a 24 hour precipitation total as well. Most of these sites unfortunately do not record any wind data. These cooperative observers play a key role in providing weather and climate information that supplements the automated sites. In many rural areas the cooperative observers are the sole source of weather data.

<u>Radar</u>

Radio detecting and ranging (radar) has been used in weather forecasting since the 1950's. Currently most of the contiguous USA is covered by the NWS radar umbrella, with the exception of some regions in the mountainous west and parts of Alaska. Radar is a useful tool because it indicates the location and height of clouds, the speed and direction of cloud movement, as well an estimate of lower and middle tropospheric wind speeds. Radars transmit radio waves that are reflected from cloud droplets and ice crystals. When the return signal is compared to the original signal, the computer processor is able to determine the relative strength of the signal. A strong signal indicates a cloud that contains a large number of droplets and or ice crystals, while a weak signal indicates a cloud that is not as dense. The return signals are assigned values and colored for display. The limitations of these radars is that they scan a limited volume of the sky, in addition, their range is limited to a distance of about 275 km (170 mi) from the transmitter. You should note that as the original signal leaves the radar, it travels on a slant path that increases in height as it moves away from the transmitter. In fact weather radars transmit radio waves at a number of different path angles with respect to the ground, as illustrated in Figure 6.1. For example, at a distance of 100 km (61 mi) from the transmitter, the signal that is closest to the ground is already about 1240 m (4,050 ft) above the elevation of the transmitter, and at 200 km (122 mi) it is 3310 m (10,860 ft). This means that radar signals frequently over-shoot low clouds. As a result, radars are of little use during episodes of fog and in situations dominated by low stratus clouds.

Another radar limitation is the fact radio waves are blocked by mountains. A number of schemes have been developed in attempt to compensate for this, however the bottom line remains that radar coverage in the western USA is far from complete. In addition, radars are used to estimate rainfall rates, they do not measure precipitation directly. The return strength of the returned signal and the height of the cloud are compared with observed data to derive rainfall rates. It is important to realize that due to the aforementioned limitations, radars are primarily used for short-term forecasting (called 'nowcast'). One of the primary reasons that the weather radar network exists in the U.S. is for the 'early' detection of what is termed server weather- thunderstorms and tornados.

Satellite Imagery

Photos (i.e.-'images') taken from satellites have been used in weather forecasting since the early 1960's. There are many different types of satellite systems currently in use, however, they are usually grouped by either the type of senors that are on-board, or by the type of orbit the satellite is in. A single satellite can have a number of different sensors. These senors are like very expensive cameras that take snapshots of the atmosphere, recording electromagnetic radiation over three prominent wavelengths: infrared, visible, and microwave. The reason we use these different wavelengths is because each one is capable of viewing different phenomena in the atmosphere. For example, microwaves can penetrate clouds, while infrared wavelengths are used to observe and track clouds at night. Visible images are good for tracking low -clouds and fog. Besides tracking cloud movement, many different products are generated from satellite images, some of the more common ones are: wind speeds, areal extent of snowcover, estimates of the amount of water vapor in the atmosphere, and sea surface temperatures. Satellite images do give a glimpse of future weather, however, the interpretation of the images is the difficult part. Just because a satellite image shows a mass of clouds located 700 km (430 mi) off of the Oregon coast, does not necessarily mean that it is going to start to rain in the Cascades in 36 to 48 hours from the time the image was captured.

Satellites are placed in several different kinds of orbits: a geostationary orbit is one in which the satellite remains fixed with respect to a point on the earth's surface. Other satellite's are in a low altitude (400-1000 km) orbit in which it moves either from pole-to-pole (polar orbit), or at some oblique angle across the earth's surface. These satellites travel at a high rate of speed so they can complete an orbit around the earth in about 90 minutes.

Misc. Tools

There are several additional tools in a forecasters arsenal that are worthy of mention. First and foremost are the twice daily launches of the weather balloons which occur at the same time (00Z and 12Z) all over the world [Note that 12Z means: twelve hours Zulu, which is equivalent to Greenwich Mean Time]. The information gathered from these balloons is either called upper-air data or sounding data. The number of weather stations which release balloons globally ranges from 300 to 400. The distribution across the planet is not uniform however, Africa for example does not have the same density of stations as Europe, nevertheless there are balloons launched in some pretty remote locales. The data collected by these balloons forms the backbone of the data sets used to initialize computerized weather models. In addition, a forecaster might want to examine balloon data from a nearby station in order to look at temperature inversions or the change in wind speed and direction with height.

In a rather unique program, a number of commercial airlines have equipped some of their aircraft with special meteorological instruments that transmit data back to a central receiving station in near real-time. Also, in one of the promising new technologies that is being developed, light weight radio-controlled aircraft will be used to fly over remote parts of the world where there is no balloon data. These flying meteorological weather stations are capable of measuring winds, temperatures, relative humidity, and air pressure. This new technology will help improve collection of weather information over the data sparse oceans.

Computer Models

The use of computers to solve the fundamental equations that govern the dynamics and thermodynamics of the atmosphere is called Numerical Weather Prediction (NWP), and has been around in some form since the late 1960's. There are many different types of NWP models, they can be grouped based on: the size of the area covered by the model (know as the domain), distance between grid points (grid interval), and numerical schemes, to name a few. However, the most common classification is based on how far out into the future the model is run. We currently have: nowcasts (0-6 hours), short range (6-48 hours), extended (2-5 days), long range (5-10 days), and climate models.

These models are started, or what we call 'initialized', with data that represents current weather conditions. They are then allowed to run for a given time, during which they output data at specified model times (like every 3 or 6 hours). Below is a short overview of model characteristics, note that modifications and refinements do occur from time-to-time. In addition, as the speed of computers continues to increase, many models are run with smaller grid intervals (higher resolution). Also note that due to the fact the earth is a sphere, grid intervals vary from one point on the globe to another, therefore the grid intervals listed below are approximate values. Most NWP models are at a minimum run at 0Z and 12 Z because these are the two times per day that balloon data is collected. A good web-site that describes model characteristics can be found at:
www.nco.ncep.noaa.gov/pmb/products

* Eta: ('a-tuh') The name stems from the type of vertical coordinate that is used. There are a number of different Eta grids, several of which are considered mesoscale. As of the summer of 2002, the Eta was being initialized at 00Z and 12Z, after which the model is run out to 60 hours.

There are shorter run cycles at both 06Z and 18Z. This model will continue to be modified and run at higher resolutions. The domain covers all of North America and parts of the Pacific Ocean.

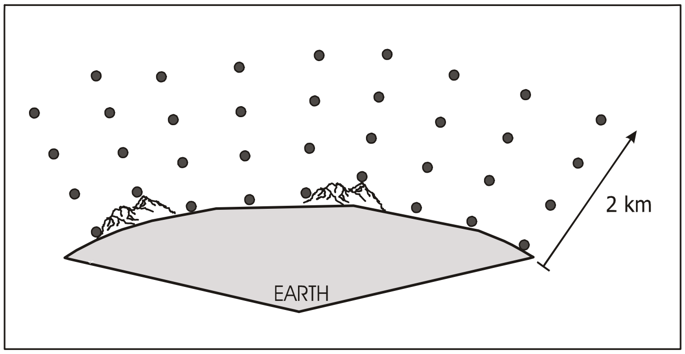

Figure 6.2- Idealized example of a NWP model grid, where the horizontal scale has been contracted. The dots represent points where the model equations are solved at every time step.

* NGM: The Nested Grid Model has been around for many years and will slowly be phased out over the next decade. The grid interval is about 70 km at 40° N. It is run at 00Z and at 12Z. Domain covers North America and most of the Pacific Ocean.

* RUC: Is a hybrid model that is primarily used for short-term forecast (0-12 hours). The name means Rapid Update Cycle and the grid interval is approximately 40 km. This model incorporates alarge amount of 'non-standard' data for its initialization. It has gone through considerable refinement since its inception, and will continue to in the foreseeable future. Current domain covers continental USA and southern Canada.

* AVN/MRF: The Aviation and Medium Range Forecast models differ from the previous three in that the domains covers the entire Northern Hemisphere. The AVN is displayed as the first 84 hours of the 240 hour MRF. There are some additional differences that are not worthy of mention at this point. The approximate grid interval is 75 km. The AVN is run at 00Z, 06Z, 12Z, and 18Z, while the MRF is run daily at 12Z.

* NOGAPS: This is a USA Navy model that has a grid interval of about 85 km. The domain covers the entire globe. The run times are 00Z and 12Z at which time the model is run out to 144 hours. NOGAPS stands for Navy Operational Global Atmospheric Prediction System

* MM5: This is a limited area model that is being run by a number of different research groups and agencies around the world. The name means Mesoscale Model version 5.0. The domain size and location varies from one application to another but typically consists of three or four nested grids with the smallest grid interval on the order of 4-10 km.

* ECMWF: Is a Northern Hemisphere model that has a grid interval of 60 km. It is run once per day at 12Z. The ECMWF acronym represents the European Center for Medium range Weather Forecasting, which is a consortium of 21 European and Mediterranean countries.

NWP models consist of a series of equations that are solved at individual points within the area covered by the model (Figure 6.2). These models do include mountainous terrain as well as large lakes and oceans. The typical model atmosphere consists of 30 or 40 layers, which extends from the surface of the terrain into the middle stratosphere. The model equations estimate future values of atmospheric variables such as air temperature, pressure, geopotential height, water vapor, wind speed and wind direction to name a few. The equations are solved at every model time-step, which varies from model to model but is within the 10-60 second range. Model output consist of numerical values of each atmospheric variable at each grid, which are then run through a graphics program that converts them into contoured maps of temperature, wind speed, or geopotential height. Output is often displayed on a given level (i.e.-surface, 500 mb), but vertical slices are equally important as well.

NWP models do have a number of limitations, for example, the more grid points contained within a model, the longer it takes the model to run before it can produce any output. Most NWP models have horizontal grid intervals that range from 80 km to about 20 km (49-12 mi). Grid intervals are important because they determine the resolution of the model, not only of atmospheric phenomena, but of the underlying terrain as well. With a grid interval of 40 km (24 mi), for example, the mountainous terrain of the western USA is poorly resolved. In fact to portray the terrain of the western USA realistically, the grid interval should be on the order of 5 km (3 mi). There is a trade-off between a model that covers a large area and has a grid interval of 80 km (49 mi), and a second model that covers a much smaller area but as a grid interval of 20 km (12 mi). Both of these types of models play a role in weather forecasting.

Overall, NWP models simulate synoptic-scale phenomena quite well, but do not perform consistently on the smaller-scales. Likewise, NWP models do a better job of simulating weather in the middle and upper troposphere, than they do near the ground. What this means to the forecaster is that they have to mentally adjust the model output so that it reflects smaller-scale effects, especially in mountainous regions where model terrain is often only a rough representation of the real terrain. If you spend any time looking at NWP output, you will notice that there can be considerable disagreement among the various models. In order to understand what a range of possible solutions looks like, an ensemble approach is used at times. For example, let's say we plotted on one graph the position of the 5300 m height field as it crosses North America (approximately the 500 mb level), from all the available NWP models. This graph, besides having a lot of lines on it, would represent a range of the most likely positions of the 5300 m height. If the lines on this graph are widely spaced there is little model agreement, conversely if the lines are very close or superimposed on each other, there is good agreement and the forecaster can proceed with the confidence that all of the models are predicting the same thing (at least for that particular variable).

In the U.S. the division of the National Weather Service that develops and runs NWP models is called the National Center for Environmental Prediction (NCEP---www.ncep.noaa.gov). Other countries have similar agencies. The NWS is not the only player in numerical weather prediction however, each branch of the military runs their own suite of models, as does numerous research groups. Since the mid-1990's a number of mesoscale or limited area models have been turned into operational NWP models. These models have the highest resolution of any of the current NWP models. In the USA the most common limited area model is MM5. The true beauty of limited area models is that they can run on small computer platforms and they can also be set-up to simulation atmospheric flow over any portion of the earth's surface, as long as there is data available for initialization. The caveat of these models is that higher resolution does not guarantee a better weather forecast. The limiting factor is the low resolution data used to initialize these models. The old computer adage: if you put junk in, you get junk out, certainly applies in this case.

Climate models on the other hand, which are not actually considered a part of NWP because they are not used in operational weather forecasting, are important research tools. Climate model simulations can span decades or centuries. The reason researchers would want to run a climate model is to investigate what repercussions a change in a particular climate element, like the doubling of CO_2 for example, has on the global climate.

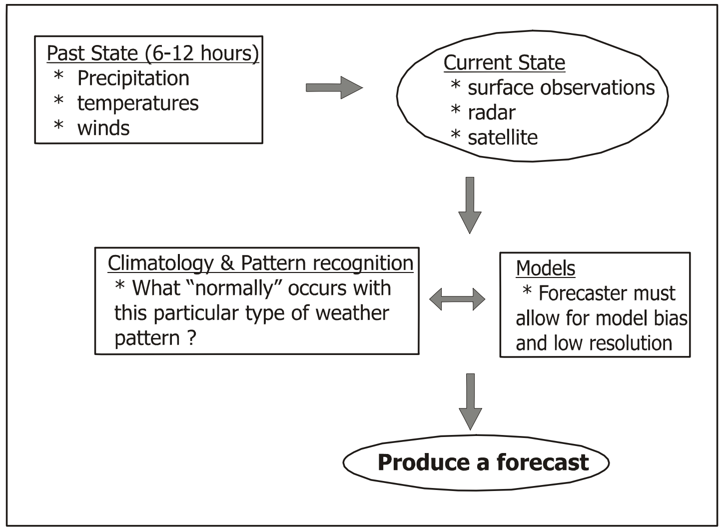

Figure 6.3- Weather forecasting decision flow chart.

Anatomy of a Forecast

In this section we will outline the steps that a forecaster goes through in order to construct a forecast. If you want to develop your own forecasting skills then you should consider using these steps as a guideline. One important point to keep in mind is that a professional forecaster has access to more data and more tools than you will ever have, not to mention many years more experience. Your goal should not be to try and out forecast the professionals, rather your efforts should go into understanding what kinds of mountain weather are produced by the various types of synoptic-scale weather patterns. In addition, in time you should attempt to understand what factors influenced the forecaster, how confident is the forecaster in their assessment, and what could cause the forecast to go wrong. These are not easy to detect, however, you can get a feel for a forecaster's confidence by the terminology they use: "rain likely" versus "chance of rain" for example indicates that there is some doubt in the mind of the forecasters to whether it is going to rain or not. Here are some forecasting tips.

Step One: Consider the current and past state of the atmosphere

This is important because weather is a sequence of atmospheric events that occur in succession. This involves looking at a surface weather map to see where the lows, highs, and fronts are located, and where they have moved from over the past 6-12 hours. It also includes an examination of surface winds, temperatures and precipitation for stations in and around the forecast area.

Step Two: Consider the future

Given the past and current state of the atmosphere, it is time to consider what is going to occur. There are two fundamental methodologies which are used: 1) Given the current conditions the forecaster uses their knowledge of past events that had a similar characteristics, to extrapolate into the future (pattern recognition). Here is a hypothetical example, a cold front has moved into the Wasatch Range, where moderate snowfall has been reported over the past 4 hours. A forecaster in Salt Lake City knows from past experience that the movement of cold fronts is often impeded by the steep terrain of northern Utah. Therefore, the forecast may reflect an additional 3 hours of moderate snowfall in the mountains, followed by diminishing snow showers in the following 6 hour period. The forecaster has now formed a pre-conceived model of what they think is going to happen, even before consulting the NWP models.

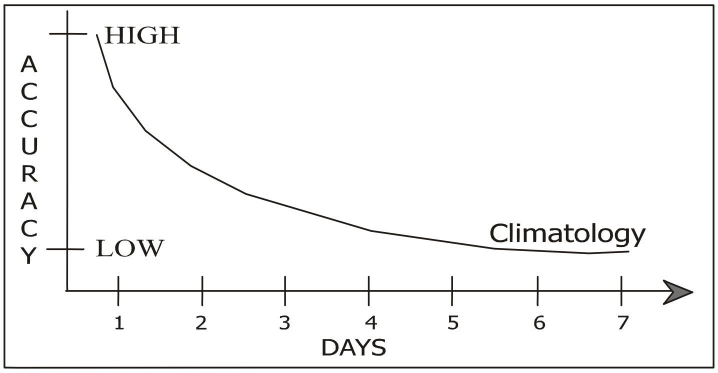

Figure 6.4- Hypothetical curve showing the decrease in forecast accuracy as time increases. Climatology refers to the longterm average weather on that particular day.

2) The second method involves examining NWP model output. In a forecast office a meteorologist will look at all of the available models for a given time period, and pick the one model which seems to have initialized the closest to reality. Note that a surface pressure map is drawn every six hours by the NWS which then can be use to compare the models against. In addition, an important consideration is how well the various models have preformed over the past several days. In other words, identifying which models have a good 'track record' and which ones do not. Once a model has been selected, a forecaster will typically look at least at the following fields:

- surface: pressure and winds
- precipitable water
- 850 mb: geopotential height field, temperature, relative humidity
- 700 mb: geopotential height field
- 500 mb: geopotential height field, vorticity, temperature advection
- 300 mb: wind direction and wind speed (jet stream)

The questions that the forecaster needs to answer are: ●where is the jet stream positioned? ●Where are the mid-tropospheric and surface highs and lows going to move to during the forecast period? ●Are any major changes in the temperature field going to occur during the forecast period? ●Where is precipitation going to occur? After the forecaster has familiarized themselves with the model output, they will often refer back to their pre-conceived model and make any necessary modifications. It is at this step that the forecaster takes the model's synoptic-scale solution and adjusts to the local-scale (Figure 6.3). This includes adjustment for deficiencies in model terrain.

Step Three: Constructing a forecast

Forecasts are written for different time periods and for different areas (often called zones). The primary elements in a forecast are: high and low temperatures, wind speed and direction, cloud cover and possibility of precipitation. Other elements are added as needed. As a consumer of weather products keep in mind that from a statistical prospective, the further out in time a forecast is made for, the lower the probability that it will be accurate (Figure 6.4). There is a trend in recent years for weather forecasts to be extended further out into the future. Many commercial and NWS products include a seven day forecast. Our advice to you, is to view these products with a lot of scepticism. Anyone who tries to forecast clouds and precipitation beyond three days is trying to 'snow job' the consumer. It is fine to outline general weather trends in extended forecasts, but the specifics are a big unknown. This does not mean that during certain weather patterns, particularly when a persistent ridge of high pressure dominates the weather, that an extended forecast is going to be a total failure. In addition, temperatures are much easier to forecast than are clouds and precipitation. However, over the course of time you will find that extended forecasts frequently do not verify. In a slightly different vein, there are legitimate climate forecasts, often called seasonal forecast, where the climate guru's have run a number of their models in an attempt to predict climate trends like droughts, significant temperature anomalies, etc.

In order to help you comprehend the intended meaning of forecast products, below is a list of some of the more commonly used terminology .

- Low Clouds- typically used to denote overcast skies (stratus) with cloud bases within about 1 km (0.6 mi) of the ground.
- High Clouds- cirrus, cirrostratus, altostratus
- Marine Layer- stratus clouds that form over the ocean but subsequently move onshore. The term 'Marine Air' is often used to denote cool/moist air that is moving onshore-this air mass may or may contain clouds.
- Fog- a stratus cloud that is in contact with the ground. Can be patchy or extend over a very large area.
- Daily Mean Temperature- the average of the daily maximum and daily minimum temperatures.
- Probability of Precipitation (POP)- the probability that a precipitation gage or gages will receive <u>at least a trace amount</u> of precipitation over a given forecast period. The POP in and of itself says nothing about total <u>amount</u> or <u>intensity</u> of the precipitation that is expected.
- Drizzle- very light continuous rain.
- Showers (snow or rain)- intermittent snow or rain, does not say anything about intensity or amount of precipitation. Can be from stratiform or convective clouds. Often reserved for post-frontal precipitation, but usage may vary from forecast office to forecast office.
- Blizzard- high winds that lift snow from off of the ground producing low visibility. Often occur after actual snowfall event.
- Freezing Rain- cloud droplets that freezing on contact with the ground, trees, powerlines, etc.
- Flurries- light snowfall but with little accumulation.
- Virga- rain that falls from a cloud (usually Tcu or Cb) that evaporates before reaching the ground.
- Thermal trough/low- A mesoscale area of low pressure that develops due to heating of the ground (and adjacent air) over a period of several consecutive days. Typically occurs during the summer.
- Thunderstorm- Cb that produces lightning, moderate to heavy rain, and quite often hail.
- Advisories, Watches, and Warnings- these three products apply to a wide range of meteorological and hydrological events: heavy snowfall, heavy rain, thunderstorms (hail, tornadoes), high winds, extreme wind chill, to name a few. Different offices of the NWS have different criteria which are used to determine which of these products should be issued, therefore we will only give a generic description.

The difference between an advisory and a warning is the intensity of the event, let us use high winds as an example. If the wind speeds are forecasted to be of moderate intensity but still strong enough to be considered a nuisance, then an advisory is issued If the forecasted winds are going to produce more than minor damage, then a high wind warning is justified. Some offices differentiate between watches and warnings based on how far in advance the product is issued. If high winds are expected to begin 18 hours from the current time, most forecasters would issue a watch, to initially alert the public. During the course of those 18 hours, if the expected high winds turned out to be a sure bet, the forecaster would then upgrade the watch to a warning. The idea behind this strategy is that warnings should only be issued when there is a high probability that it is going to happen. This reduces the number of 'false alarm' warnings that are issued.

Trip Planning and Field Forecasting

Forecasting the weather from a weather office where all of the data is available at a persons finger-tips is one thing, but it is a completely different ball game to do it while hiking over hill and dale. The following are some suggestions of information you should gather before you pull out of the driveway or board the 747 for the Himalaya. We have also included a short list of weather elements that you should pay particular attention to once you are in the mountains.

<u>Local Trips</u>

● The current and forecasted position of the jet stream(s). The mid-latitude storm track follows the jet stream, so knowing its position is valuable.

● Read forecast discussion issued by the nearest office of the NWS to your destination. How uncertain is the forecast? Keep in mind that uncertainty can be a result of model discrepancies, transition from one weather system to another, or due to the simple fact that your destination is going to be on the fringes of a storm.

● You can also hear weather reports and forecast via NOAA Weather Radio. These broadcast are made on frequencies not normal to AM/FM radios, so you have to buy a special radio. Nevertheless, these radios are pretty cheap and can be carried into the backcountry as well. Contact your local National Weather Service office for more information.

● Attempt to find out what temperatures and winds you should expect for a given altitude range. This includes the approximate height of the freezing level.

● Where are the fronts and how are they expected to move. Is there going to be any stratiform precipitation? Has it been convective for the past several days? What are the possible weather threats: lightning, high winds, extreme cold, etc.

● When you arrive in the mountains, observe the current conditions. <u>Do these observations conform to your conceptual model of what the weather should be? If you answer NO- reevaluate</u>. Is the weather better or worse than expected? If it is considerably worse, you may need to alter your plans, or be prepared to alter plans as the day progresses.

● Once you have returned home, it is important to compare the forecast with what occurred. If the forecast was a poor, try to find out what went wrong. Also ask yourself what you may have learned about mountain weather while on the trip.

● Several NWS offices produce summer forecasts for a number of National Parks, including those frequented by climbers: Denali and Mt. Rainier National Parks in particular. These forecasts include the usual generic weather forecast, but also contain wind and temperature forecasts at higher elevations. See the respective sections in Chapters 7-9 for more details and web-sites.

Extended Trips–Over Seas

Trying to find weather and climate information on any of the worlds's remote mountain ranges, can be quite exasperating. Here are some hints.

Pre-Trip:

• Read the appropriate chapter(s) on regional weather surveys in this book. Pay close attention to seasonal storm track information. You want to answer the following questions: When is the 'dry' season? What is the seasonal wind pattern? Are there any unique weather phenomena that I should be aware of?

• The best region-by-region description of climate, which covers the entire planet, can be found in a multi-volume work entitled: *World Climatologies*. This monumental work is somewhat dated, nevertheless it is a wealth of information. It can be found in some larger libraries.

• Get on-line with the National Climatic Data Center (NCDC), they also have some data outside of the USA because they are a designated archiving agency within the World Meteorology Organization. In addition, most countries have some type of weather service, which usually archives climate data. Some of these have useful web-sites, see the end of this chapter as well as the weather summaries given in Chapters 7-9 for website listings

• Learn from other climbers, both their mistakes as well as successes. Read books and climbing accounts as well as on-line bulletin boards that cater to climbers. You can also find out when commercial expeditions or guide services run trips to a particular mountain region. Since these services are trying to generate a profit, they generally know when the optimum weather occurs. There are few regions of the world, as you will learn in the following three chapters, where there is no optimum climbing season. In those cases mountain travelers should be prepared for serious weather delays. If waiting out extend periods of stormy weather is not on your itinerary, you should look elsewhere to satiate your climbing and hiking needs.

• Before you leave on the trip, attempt to find out what the weather has been like for the past several months. Has it been snowier, windier, colder than normal? In some regions of the world, the weather can undergo major transitions over the span of a week or two, in other regions the transition is much more gradual.

In the Mountains:

Keep in mind that the majority of the time you are not going to have access to a forecast. This is slowly changing as more and more large expeditions carry satellite communication gear. Even then however, most of the forecasts are quite general in nature. Here are the most important weather elements to pay attention to:

- Cloud sequence–In the big mountain ranges there is often rapid cloud development at 'lower' and mid-elevations which proceeds cloud development at higher (summit) levels.
- Changes in atmospheric pressure–Use your altimeter if you have one (see Excursion in Chapter One)
- Shift in wind direction- This may indicate the passage of a front or trough.
- Dramatic change in wind speed- By dramatic we mean a change from light winds to moderate or strong winds over a period of several hours.
- Change in visibility-- this is less reliable than other methods but at times can signify an increase in low or mid-level moisture. Meteorologists call very small non-cloud water droplets: haze. These droplets condense and re-evaporate rapidly, and they generally do not become large enough to form cloud droplets. If for example the previous four days had been very clear, and on day five the winds increase and there is a noticeable layer of haze, it could be a pre-cursor to increased cloud development.
- Increase in upper or mid-level tropospheric wind speeds before the winds at lower elevations increase. This occurs frequently on higher mountains because the summits of these mountains lie close to the jet stream.

If the weather has been good for a period of time but then you start to notice increased cloud development (more than on previous days), or the signs of an approaching front, and/or an increase in wind speeds, you should keep a close watch on the weather. A number of people fail to do this each year, and end-up 'buying the farm' (see Chapter 1). Conversely, if the weather has been stormy for a period of time, and the winds begin to diminish, and the clouds thin out, there is a reasonable chance that the storm is in its final stages. Beware of 'sucker holes' however, these are lulls in a storm that lure climbers away from the safety of a camp, only for the storm to re-intensify.

Professional Profile
An Interview with Jim Woodmencey

Jim is a meteorologist and owner of MountainWeather (www.mountainweather.com), a weather consulting business based in Jackson, Wyoming. He is the on-air meteorologist at KZJH Radio and the author of the book: Reading Weather. Jim has also worked as a climbing ranger in the Tetons and as a heli-ski guide.

Q1- Is the average backcountry skier weather cognizant?
JW- I would say the average backcountry skier is not that weather cognizant, but the more experienced skiers are. Skiers who have been through even a basic avalanche course understand the importance of weather and its affect on the snowpack and avalanche conditions.

Q2- Do monthly or seasonal changes in the weather factor into the formation and release of avalanches?
JW- In the early season (October through December in the Rockies), the snowpack that already exists

is greatly affected by longer-term weather patterns. For instance, a long dry spell with clear skies and cold temperatures can weaken the existing snowpack and set up a dangerous avalanche situation later in the winter as snow eventually accumulates on top of this weaker base layer.

As warmer weather approaches in the late winter and early spring the snowpack will tend to strengthen through settlement and consolidation. However, a warm-up that occurs too rapidly can be responsible for widespread avalanche release.

Q3- How much of a threat is lightning to mountain travelers in the central and northern Rockies?

JW- Lightning is perhaps the most significant weather threat that mountain travelers have. Too little attention is paid to approaching and developing thunderstorms by folks in the mountains. A few important facts about lightning are worth remembering. Lightning is five times more likely to strike in the mountains than it is nearby valleys. In addition, lightning has been known to strike 'out-of-the-blue' from 5 to 10 miles away.

Q4- What role do you see the Internet playing in the dissemination of weather/climate information to mountain travelers?

JW- Next to watching The Weather Channel, the Internet is the world's most accessible source of weather information. The problem for the user lies in finding relevant forecasts for the higher elevation locations they are traveling to. An additional complication is the user being able to interpret satellite, radar and computer model products without the training and experience of a meteorologist. With the recent computer and communications technology advances, using computers in the mountains to receive and analyze weather information on–the-spot may become more commonplace (Jim provided forecast for a spring 2000 Everest expedition).

Although, despite all of the new technology, it is my opnion that the NOAA Weather Radio is still the cheapest, lightest, and most portable way to get update forecasts in the mountains throughout most of the USA.

Climate: What is it?

Climate can be defined as: the long-term average weather. This simple definition is however, in need of further clarification. When the term 'weather' is used, what we really mean are weather elements that can be measured, such as air temperature, rain, snowfall, etc. Essential we take descriptions of the weather ("July was very hot") and turn it into numerical values ("July was 4.6^{o} C above normal"). Secondly, what do we mean by 'long-term'? Unfortunately there is no precise definition, 'long-term' can mean 10 years or 10,000 years, it should be made clear from the context in which it is used.

In most countries around the world climate statistics are, for the most part calculated using 30 years of data. For illustrative purposes let's assume that you wanted to know the mean (average) daily temperature, or what is often referred to as the 'normal' temperature for April 12th in Jackson, Wyoming. Once you have collected about 30 years worth of April 12th data, you would then calculate the mean. The National Climate Data Center (NCDC), which has been commissioned to collect climate data in the U.S., does not recalculate 30 year averages at the beginning of each new year. They use a fixed 30 year period that is adjusted once each ten years. For example, currently we are using the 1971-2000 climate averages. In January of 2011, work will begin to calculate new climate normals for the years 1981 to 2010. Other agencies and researchers may use climate statistics that have a longer than 30 year record, it just depends on the purpose of the study.

In the paragraph above we used the example of daily mean temperature at Jackson, here is an illustration on how it is calculated. If the maximum temperature on a given day at Jackson is 17° C (63° F) and the minimum is 9° C (48° F), then the daily mean is a simple average of these two values or 13° C (55° F). A second but less common way to calculate the daily mean is to average the 24 temperature observations that are taken at the top of each hour. This is not common in climate statistics because the vast majority of climate stations do not record hourly observations.

Most climate stations use special thermometers that record the maximum and the minimum temperature even when no observer is around to make the observation. Another very common climate element is the mean monthly temperature. This value is produced by averaging each daily mean over the course of the month. In a similar fashion an annual mean temperature can be calculated by averaging the 12 monthly values. Table 6.2 displays the monthly mean temperature for Jackson, using both the 1961-1990 and the 1971-2000 averages. Notice how the 1971-2000 averages are up to one degree Celsius warmer than the 1961-1990 averages, this is not surprising since the decade of the 1990's was one of the warmest on record in many parts of the world. The last row in Table 6.2 represent standard deviations for the monthly means. The standard deviation (calculated for 1971-2000) is simply a range of temperatures wherein two-thirds of all the values can be found. For example, the January standard deviation is 2.6° C (4.7° F) while the mean is -8.3° C (17° F). This can be understood to mean that two-thirds of the 30 values (one for each year) fall within the -10.9° C to -5.7° C range (calculated as -8.3° C ±2.6°). Also notice that during the warmer months of the year, the standard deviations are much smaller than in the winter. This is a result of the fact that during the winter, large temperature fluctuations occur because of the formation and dissipation of low-level temperature inversions.

Table 6.2- **30 year monthly mean temperature for Jackson, Wyoming.**

years	°C	J	F	M	A	M	J	J	A	S	O	N	D	**Ann**
1961-1990	°C °F	-9.3 15.3	-6.7 19.9	-2.2 28.0	3.1 37.6	7.9 46.2	12.5 54.5	16.2 61.2	15.0 59.0	10.2 50.4	4.6 40.3	-2.3 27.9	-8.9 16.0	**3.3** **37.9**
1971-2000	°C °F	-8.3 17.1	-6.4 20.5	-1.1 30.0	3.5 38.3	8.1 46.6	12.9 55.2	16.3 61.3	15.5 59.9	10.6 51.1	4.8 40.6	-2.3 27.9	-8.6 16.5	**3.9** **39.0**
St Dev.	°C °F	2.6 4.7	2.5 4.5	2.3 4.1	1.6 2.9	1.2 2.2	1.4 2.5	1.6 2.9	1.4 2.5	1.4 2.5	1.4 2.5	2.1 3.8	3.2 5.8	**0.8** **1.4**

Precipitation statistics are calculated in a similar fashion as temperature, with the notable exception that there is, of course, no maximum or minimum daily precipitation, only a daily total. Most climate precipitation statistics are based on monthly or annual values. Remember that precipitation is a combination of rainfall and the water equivalent of the snow that fell over a given period of time. For example, if 0.7 cm (0.27 in) of rain fell at Jackson during the day on March 31, but an additional 10 cm (3.9 in) of snow fell that night, before midnight. What do you think the daily precipitation would be if the water equivalent of the snow was 0.8 cm (0.31 in)? The daily total precipitation on March 31 would be 1.5 cm (0.58 in). In addition, during the winter months climate stations keep a running total of that seasons total snowfall. Let's say that the seasonal snowfall up to midnight on March 30 had been 161cm (63 in), obviously the new seasonal snowfall total would be 171 cm (67 in) as of midnight March 31.

A host of additional climate variables are compiled by different agencies, some of the more common ones are: thunderstorm days, average daily wind speed, daily peak wind gusts, snowfall, hours of sunshine. The best web-site to view climate data for the western USA is at the Western Region Climate Center (www.wrcc.dri.edu)

Weather and the Internet

With the advent of the Internet, weather information has gone from the realm of being hard to find, to more information and data than you could possibly use. Virtually every office of the National Weather Service has a website where they post forecasts as well as weather discussions, and a hosts of tools such as: satellite images, model data, sounding data, etc. You should be aware that these websites are typically not standardized, meaning one office may have considerably more tools and goodies than another office. In addition, many universities with a meteorology or atmospheric science department will have a website with numerous links. And of course there are commercial ventures that provide weather data either free or for a charge. The following is a list of places to begin your weather search.

General Weather Information:

- Weather Underground: **www.wunderground.com**
- The Weather Channel: **www.weather.com**
- National Weather Service (NWS): 136 forecast offices nation wide, in addition to a number of related research facilities that all have obscure acronyms.
  http://iwin.nws.noaa.gov
  www.nws.noaa.gov
- Environment Canada: **http://weatheroffice.ec.gc.ca/canada_e.html**

Model Output:

- University of Michigan: **www.yang.sprl.umich.edu/wxnet/model**
- NCEP: **www.ncep.noaa.gov**
- ECMWF: **www.ecmwf.int**
- MeteoSwiss (Switzereland): **www.meteoschweiz.ch**
- **http://weather.unisys.com**
- **http://twister.sbs.ohio-state.edu**
- **www.aos.wisc.edu/weather/index.html**
- Navy (use public access button): **www.fnmoc.navy.mil**

Upper Air Data:

- Forecast Systems Laboratory (FSL): **www.fsl.noaa.gov**

Satellite

- NESDIS: www.nesdis.noaa.gov
- Colorado State University: **www.cira.colostate.edu**

Climate Data:

- National Climatic Data Center (NCDC)- Archives data for NWS. It also has limited climate data from around the world. Some of it is free and some cost $. **www.ncdc.noaa.gov**
- Western Regional Climate Center: **www.wrcc.dri.edu**
- Climate Prediction Center (CPC): **www.cpc.noaa.gov**
- Climate Diagnostics Center (CDC): **www.cdc.noaa.gov**

Snow Data:

- National Resource Conservation Service (NRCS)- This is the organization in the USA that is mandated by the Federal government to collect snow data. They operate snow courses and snotel sites (automated snow senors). Water Resources and Climate Center: **www.wcc.nrcs.usda.gov**
- California Snow Cooperative: **www.cdec.water.ca.gov/snow**
- National Snow and Ice Data Center: **www-nsidc.colorado.edu**
- Swiss Federal Institute for snow and avalanche research: **www.wsl.ch/slf**
- Avalanche Forecast Center: **www.avalanche.org**
- Northwest Weather and Avalanche Center: **www.nwac.noaa.gov**

Lightning

- Pueblo Forecast Office: **www.crh.noaa.gov/pub/ltg.shtml**

Research

- National Center for Atmospheric Research (NCAR): **www.ncar.ucar.edu**

Misc.

- Mt Washington Observatory: **www.mountwashington.org**
- World Meteorological Society (WMO): **www.wmo.ch**

Chapter Quiz

1. True/False: Weather balloons are launched at the same time no matter the location?
2. Name at least two NWP models.
3. True/False: Radar can be used for long-term weather forecasting?
4. What is freezing rain?
5. True/False: Climate data is of little value when you are planning a major overseas expedition?
6. True/False: Lightning is not a hazard in the Rockies?
7. True/False: The mid-latitude storm track is closely associated with the sub-tropical jet stream?
8. What range of wavelengths (visible, infrared, microwave) are used in satellite imagery to view/track clouds at night?