15 Weather Forecasting

Learning Goals

After studying this chapter, students should be able to:

1. explain how weather observations, including satellite imagery and radar data, are important in making weather forecasts (pp. 381–383);
2. describe how maps are used in weather forecasting (p. 384);
3. explain how advances in science and technology have both improved weather forecasts and changed the ways we make forecasts forecast (p. 385); and
4. appreciate why it is likely impossible to produce perfectly accurate weather forecasts (pp. 397–398).

Summary

1. Weather forecasts are made by first observing current weather conditions, then projecting these conditions forward in time using our understanding of atmospheric processes. The steps involved in making a forecast are observation, analysis, diagnosis, and prognosis.
2. Weather forecasters use a variety of methods to make forecasts. The persistence method is based on the assumption that present conditions will not change. The trend method involves identifying how the atmosphere is changing and assuming that this change will continue into the future. The analog method involves recognizing patterns from the past and assuming that they will produce the same kind of weather as they have before. The "rule of thumb" method relies on rules that have been formulated based on past observations. The climatology method involves using climate statistics to make forecasts based on averages. Numerical weather prediction is a forecasting method that relies on computers to do billions of calculations to determine future conditions based on initial conditions.
3. The invention of the telegraph, which made instant communication possible, is often regarded as the point at which weather forecasting became possible. Forecasts remained short term, and fairly unreliable, until the computer made numerical weather prediction possible. Subsequent increases in computer power and our expanding knowledge of atmospheric processes have allowed us to make increasingly sophisticated models for forecasting the weather.
4. Weather observations are required to establish the initial conditions for a forecast. The acquisition of weather data from around the world is coordinated by the World Meteorological Organization. The goal is to provide as complete coverage as possible. Satellite imagery helps us fill in the gaps left by other observational data. Visible and infrared satellite imagery provides information about the location and nature of cloud coverage. Water vapour satellite imagery provides information about the distribution of atmospheric water vapour. Radar data provide information about local storms.
5. In the analysis and diagnosis steps of weather forecasting, the forecaster makes use of weather maps for the surface and four layers through the troposphere. These maps display weather observations as well as such computer-derived values as vorticity, thickness, and vertical motion. Together, these maps allow a forecaster to develop an understanding of the weather and how it is changing. Forecasters can use maps for the upper half of the troposphere to determine if, and when, a storm system might reach a location; they can also use these maps to determine whether temperatures over a large are might be above or below normal. They can also assess jet streaks on the 250 hPa chart, and thermal advection and vorticity advection on maps of the lower half of the troposphere, to determine whether weather systems are strengthening or weakening. The 700 hPa chart is useful for finding areas of moisture in the atmosphere. A variety of forecasting rules of thumb can also be applied on these charts.
6. Numerical weather prediction is a forecasting method in which computers project current conditions into the future by performing calculations. These calculations make use of seven equations that mimic the behaviour of the atmosphere. Weather observations are used to assign values to a three-dimensional grid representing the atmosphere. Calculations are done to advance these initial values forward in time, time step by time step. In issuing a forecast, forecasters normally consult the output of several different models for guidance. It will likely never be possible to make forecasts that are completely reliable or extend much further into the future than they do

now. Ensemble forecasts are created by calculating a forecast several times but with different inputs and/or slight changes in the model. This technique has improved forecast accuracy and allows for probability forecasting.

7. Long-range forecasting relies on statistical and numerical models that are based on relationships between atmosphere-ocean interactions and weather. Long-range forecasts provide probabilities that temperatures or precipitation will be above or below normal, over periods of months.

Key Terms

Chance of precipitation The chance that measurable precipitation will fall on any random point of the forecast region during the forecast period. *Measurable precipitation* is defined as 0.2 mm of rain or 0.2 cm of snow. (p. 376)

Chaos Behaviour that is extremely sensitive to initial conditions and very difficult to predict. (p. 393)

Ensemble forecasting A forecasting technique that involves running forecasting models several times, with slight variations in initial conditions and/or the way the model operates. (p. 396)

Isotachs Lines that connect points of equal wind speed. (p. 390)

Model output statistics (MOS) A statistical method that adjusts the output of a weather forecasting model for local conditions. (p. 395)

Parameterization An approximation used in a model either when we don't understand a process well enough to represent it with equations or when the process is so complex that it would require too much computer time to adequately represent it. (p. 395)

Prognosis A weather forecast. (p. 378)

Answers to Selected Review Questions (pp. 400–401)

1. **What are the four steps in the weather forecasting process? Why is each step important?**

   The four steps are observation, analysis, diagnosis, and prognosis. Observations are important because the current state of the atmosphere must be known in order to project that into the future. The analysis phase is necessary for the production of weather maps. The diagnosis step allows forecasters to develop an understanding of the processes at work in the atmosphere and how they are changing. In the prognosis step, a forecast is generated.

3. **For each statement below, which forecasting method is most likely being used?**
   a) Thickness contours on the 500 hPa chart suggest that the precipitation will be snow.
   b) We should get about 20 mm of rain before noon tomorrow.
   c) The clouds will continue to thicken as a low-pressure system moves in to the area.

d) This steady rain should continue for a few more hours.
e) Based on past experience, we can expect it to rain almost every day this month.
f) When the jet stream comes from the southwest, our city usually gets a lot of rain.

a) rules of thumb
b) persistence
c) trend
d) persistence
e) climatology
f) analog

5. **What was the significance of each of the following scientific advances to the science of weather forecasting?**
   a) the formulation of the Norwegian cyclone model
   b) the development of the primitive equations
   c) the discovery of the Rossby waves

   a) The formulation of the Norwegian cyclone model allowed forecasters to realize that they needed to know what was happening in the upper atmosphere in order to produce more reliable forecasts.
   b) The development of the primitive equations led to the numerical weather prediction method.
   c) The discovery of the Rossby waves led to more knowledge about the upper-air flow and how it influences the development and movement of surface weather systems.

7. **How is radar useful in forecasting?**

   Radar is useful in forecasting because radio waves are strongly reflected by precipitation. The character of the reflected pulse indicates the type and intensity of precipitation. Doppler radar can detect areas of heavy rain, hail, and rotation patterns within a storm and therefore can increase the lead time for tornado warnings.

9. **What are the steps involved in numerical weather prediction? What are the possible sources of error in this process?**

   Weather observations are inputted into a computer, calculations are performed to project current conditions forward in time, and an output forecast is generated by the computer. Any errors in initial conditions will be amplified over time.

11. **What are teleconnections? How is an understanding of teleconnections useful in long-range forecasting?**

    Teleconnections are linkages that result because atmosphere–ocean interactions in one part of the world affect the large-scale atmospheric circulation in another part of the world. An understanding of teleconnections allows us to associate the weather changes with these interactions and provide useful statistics on the relationship between weather and the interactions. This information has been used to create analog statistical models to produce long-range forecasts.

Study Questions

For suggested answers, see below.

1. How does the World Meteorological Organization coordinate weather observations around the world?

2. For what are surface maps the most useful?

3. Why does the 250 hPa chart show a wave pattern that is much simpler than the more complex patterns seen on maps representing the surface or lower troposphere?

4. What are the primitive equations? List and describe each.

5. How are large-scale model outputs refined for local conditions?

Answers to Study Questions

1. All observations are made at the same time, based on Coordinated Universal Time. Instruments used for the observations are standardized, and the conditions under which the observations are taken must be the same everywhere. The WMO also ensures that both this observational data and the output of forecasting models are shared among countries. (p. 382)

2. Surface maps are most useful for determining where high- and low-pressure systems are currently located. The maps tell us where the skies are clear and where they are cloudy. A series of surface maps can help us determine the direction and speed at which pressure systems are moving. (p. 387)

3. At that height there is no strong radiative heating, little evaporation, and little friction. (p. 387)

4. The primitive equations include equations of motion that represent the horizontal movement of air, the hydrostatic equation which is used to determine vertical motions, the ideal gas law which links pressure, temperature, and density, the first law of thermodynamics which is used in the models to determine temperatures, the conservation of mass, and the conservation of moisture. (p. 393)

5. Forecasters use a statistical method known as model output statistics (MOS) to refine the large-scale model output for local conditions. MOS are created by comparing years of numerical weather prediction results to the actual weather in an area. From this, regression equations are developed to adjust the results of the numerical weather prediction forecast to local conditions. These regression equations, or statistical models, are added to the numerical weather prediction models to refine the large-scale results for given locations. (p. 395)