Guide to the Science of Climate Change in the 21st Century

Chapter 3
Weather vs. Climate

David H. Manz
PhD., P. Eng., AOE, FCAE

2020

Eco-print, “Autumn Maples”, Nora Manz 2020

Table of Contents

List of Figures

3. Weather vs. Climate

3.1 Introduction

It is very important to understand the distinction between 'weather and climate'.

Weather happens day to day (moment to moment) – best forecast is no more than 10 days. Weather typically includes parameters such as precipitation and its form (rain, snow), temperature (maximum, minimum, average), humidity, wind speed and direction, sunshine hours (cloudiness) and more. Weather forecasts may be made on an hour-by-hour basis. Weather descriptions can be used to describe local regions that might be quite small in area. A description of weather forecasting may be found in a recently published article in the newsletter, The Conversation, titled 'The science of weather forecasting: what it takes and why it is so hard to get right' by Victor Ongoma, https://theconversation.com/the-science-of-weather-forecasting-what-it-takes-and-why-its-so-hard-to-get-right-175740?utm_medium=email&utm_campaign=Latest%20from%20The%20Conversation%20for%20February%202%202022&utm_content=Latest%20from%20The%20Conversation%20for%20February%202%202022+CID_db2ba60ce0fe42e6d23e6b0031d75f98&utm_source=campaign_monitor_ca&utm_term=The%20science%20of%20weather%20forecasting%20what%20it%20takes%20and%20why%20its%20so%20hard%20to%20get%20right . The author describes weather forecasting as complex and challenging entailing three steps: observation, analysis and communication.

Climate is a long-term average of weather typically including precipitation and average temperature – averaged over a season (several months), years, decades or much longer. Climate is used to describe large regions that are geographically homogenous. Climate modelling is discussed in detail in later chapters.

The climate of a region, short and long term, will not only determine its physical nature but also the characteristics of its biosphere – plants and animals. If the climate of a region is known weather patterns can often be inferred.

The difference between weather and climate is illustrated in Figure 3.1. It shows a plot of a parameter value (any parameter) vs. month and week of the year. It is assumed there are 100 years of observation. The horizontal blue lines are the average monthly values for the entire 100 years of observations and may be considered a description of the location's climate (wrt the specific parameter considered). The red stars are average weekly values for just one of the years.

Note that the average weekly values can show significant differences from the long-term average values. Each year is unique but the general trend of the values of the parameter over the year will be observed in each of the years. Daily values of the parameter are describing weather (from which the weekly values were determined) and would show even greater variation of the parameter.

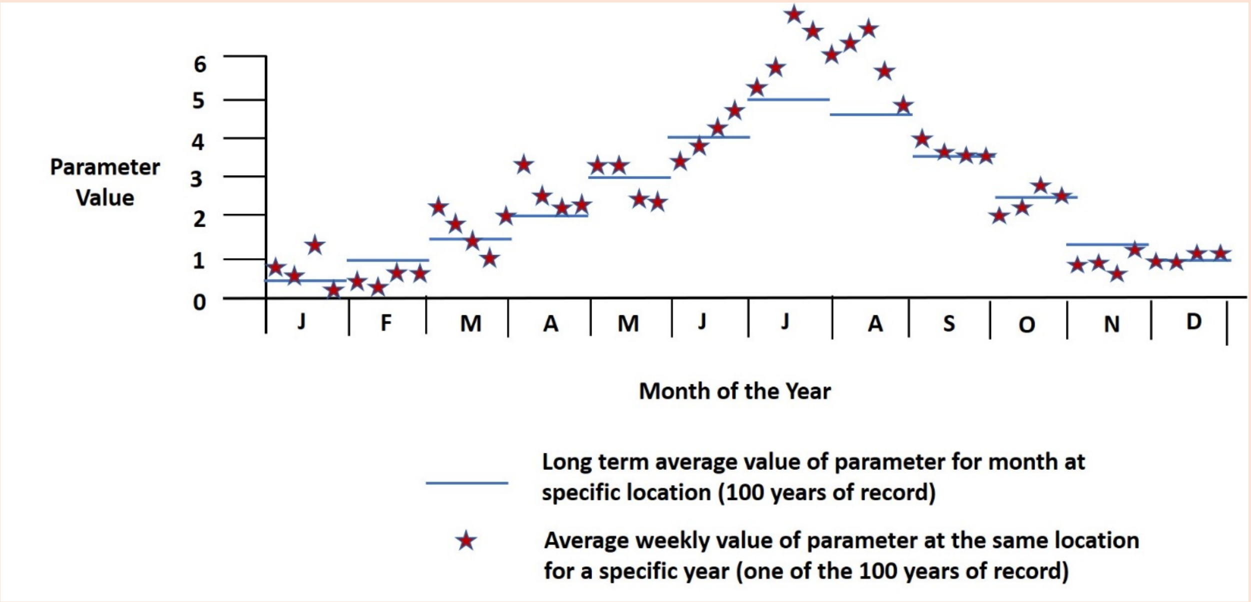

Figure 3.1 Difference between climate and weather.

We are discussing 'climate'.

There are numerous factors affecting weather and climate. Most of the major ones are shown in Figure 3.2.   The complexity is obvious. The challenge is to know what their effects are and how they relate to each other to determine weather and climate. This is possible by identifying the important subsystems and understanding how they interact. Subsystems of particular interest are the energy budget, carbon cycle and hydrologic cycle.   With this knowledge naturally occurring and human influences can then be understood.

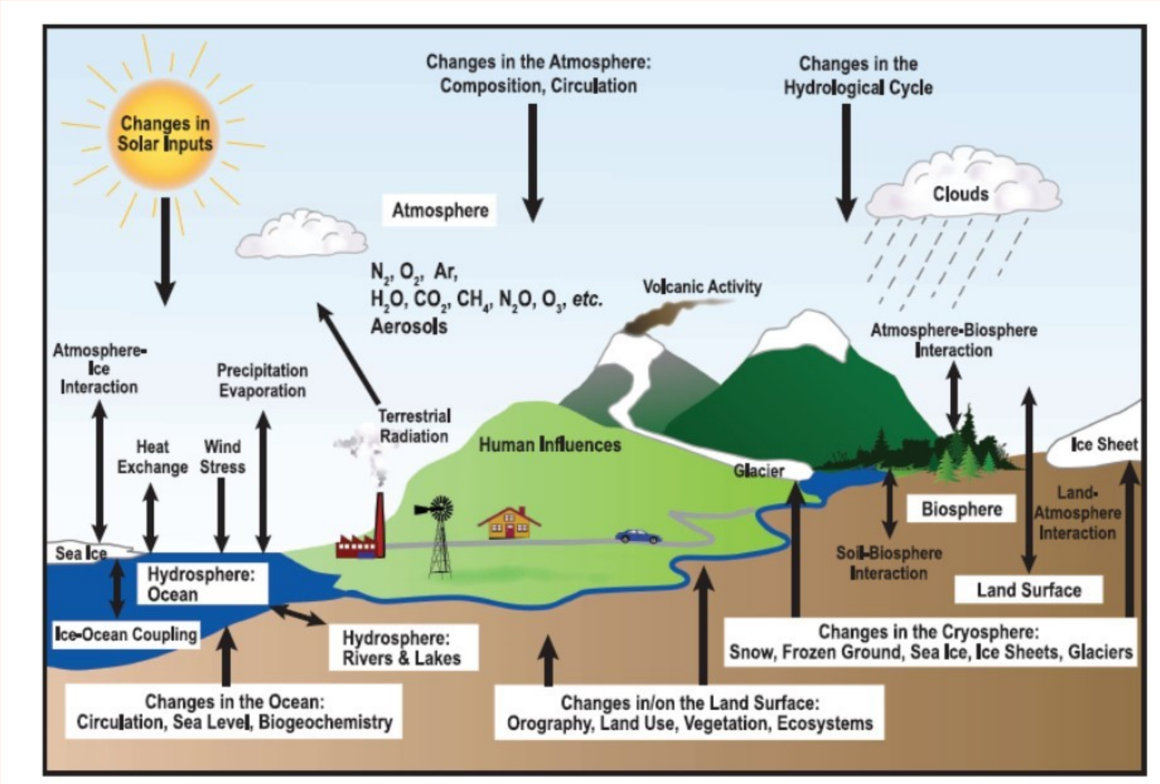

Figure 3.2 Factors affecting weather and climate.
https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-01.pdf

3.2 Weather observation and interpretation

Weather observations are collected by a special agency of the United Nations, the World Meteorological Organization or WMO (https://public.wmo.int/en/our-mandate). 'The WMO is dedicated to international cooperation and coordination on the state and behaviour of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources.' 'Within its mandate in the areas of weather, climate and water, WMO focuses on many different aspects and issues from observations, information exchange and research to weather forecasts and early warnings, from capacity development and monitoring of greenhouse gases to application services and much, much more.' The WMO web site is extensive and worth exploring.

Of particular interest is their observation program, https://public.wmo.int/en/our-mandate/what-we-do/observations , which describes the data collected, how it is collected and how it is made available. This is described in detail in the WMO Integrated Global Observing System, https://public.wmo.int/en/programmes/wigos . See Figure 3.2. To the extent possible all weather-related parameters, (including all elements of the energy budget as described in

Chapter 4), evaporation/ evapotranspiration, wind velocity and direction (vertical profile from land/ ocean surface up), and moisture content of atmosphere are archived and made available at https://climatedata-catalogue.wmo.int/ .

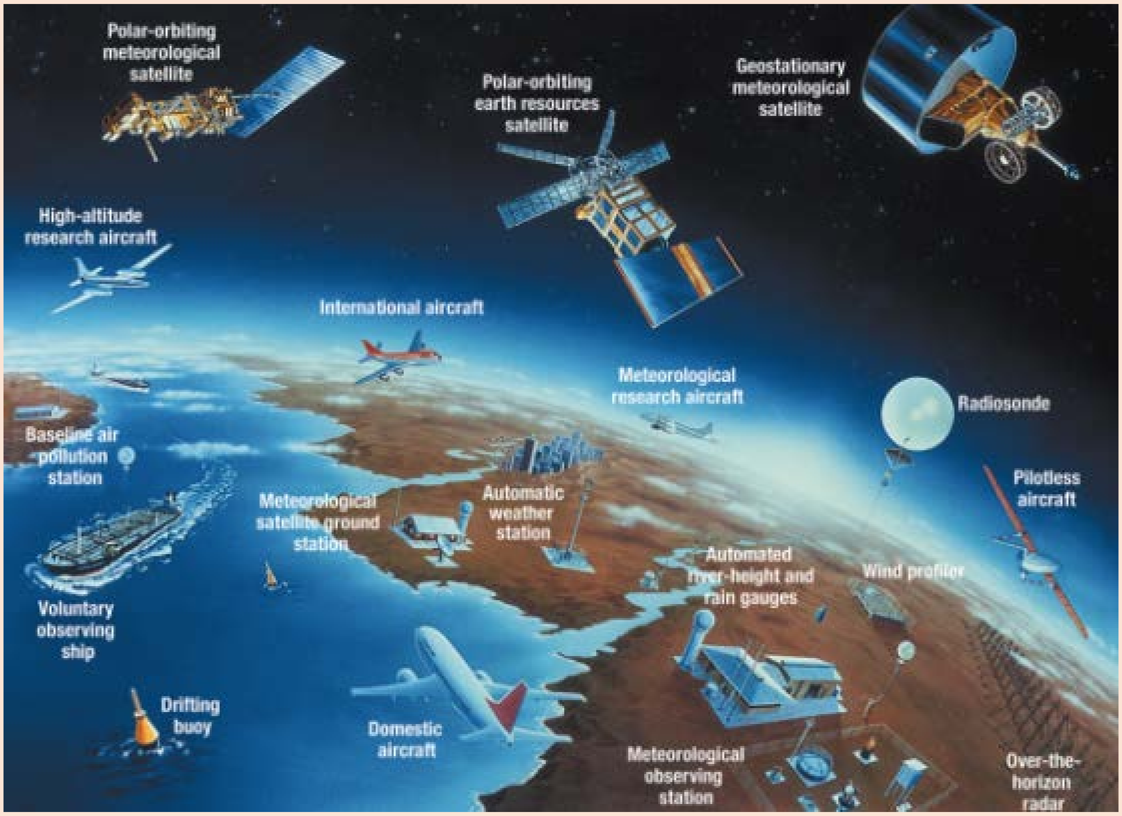

Figure 3.3 WMO global observation system.

WMO publishes a document titled, 'WMO State of the Global Climate 2022' https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate .

3.3 Canada – meteorological data availability

The Government of Canada (typical of many other governments) make historical data available through their own web site dedicated to this service. In Canada this is https://climate.weather.gc.ca/historical_data/search_historic_data_e.html . This information is available to the public without cost.

3.4 Forecasting

The data collected by the WMO and their member countries is used to for many purposes as they relate to water supply, water management (including storm water management), agriculture, building design, design of transportation systems, to name a few.

Three types of forecasting are commonly used

3.4.1 Stochastic forecasting

Stochastic forecasting is based on the statistical analysis of historical data. Stochastic forecasting depends on the availability of a significant period of historical data obtained during a stable climatic period. It is preferable to have thirty pieces of data or more - thirty years or more if annual data is used. All hydrologic parameters may be analyzed using stochastic methods. Unfortunately, many parts of the world do not have a sufficient history of meteorological data collection to perform this analysis.

The climate of a region is defined using a form of stochastic analysis to inform what the climate is and how it changes with seasons. Average characteristics and its variability are determined.

Another very important stochastic forecasting technique is used to predict how often a specific parameter will occur or be exceeded; that is its frequency of occurrence. The technique is known as frequency analysis. The specific parameter of interest (e.g., volume of seasonal rainfall over a specific region or time period) may be related to how often it can be equaled or exceeded in a specific number of years called its frequency of occurrence. Occasionally, an extreme event will be recorded within the period of record (e.g., a one in five-hundred-year event) and would be difficult to impossible to consider with the limited collection of data. This event will typically be considered a statistical outlier and not included in the analysis.

See Figure 3.4 below. For example, a parameter equal to 4 can be expected to be equaled or exceeded approximately every 100 years.

Most meteorological observations can be analyzed to produce a graph similar to that shown in Figure 3.4.

A frequently used application of this method of stochastic forecasting is predicting the frequency of occurrence of the intensity of a rainfall event over a specific area of land (watershed). This information is used to predict runoff from the rainfall that ultimately will flow in a stream or flow down streets and storm sewer system in urban environments. In one instance the size of culverts required to pass the flow or the size of the appurtences that are part of the urban storm water management system.

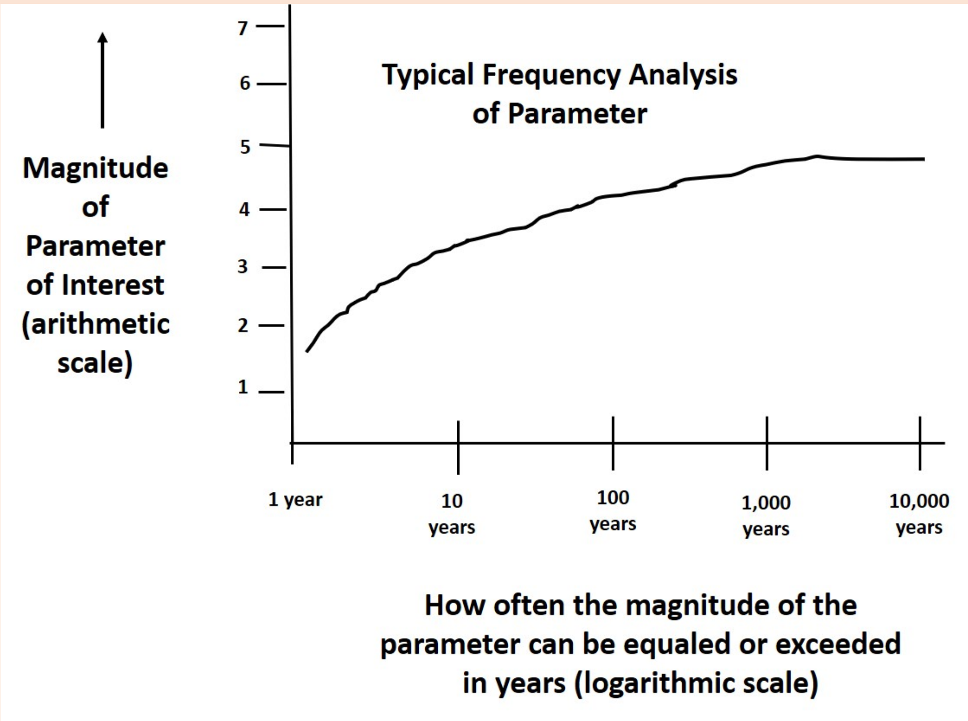

Figure 3.4 Typical frequency analysis of any parameter.

3.4.2 Real-time forecasting

Real time forecasting is the prediction of a parameter based on information obtained in real-time.

Storm tracking using satellite imagery is a type of real-time forecasting.

Weather forecasting using accurate distributed models is a very good example of real-time forecasting. There is significant demand for accurate predictions of weather. Models used for weather prediction require and process enormous quantities of data that is used in physically based models of atmospheric circulation. The output from these models may be continually updated using real-time observations including satellite imagery. Weather models require the use of the most powerful computer resources available. When there is sufficient quality data available for model input, weather predictions are quite accurate. Weather models are also a very good example of distributed models.

3.4.3 Distributed models

Distributed models require the knowledge and availability of all the underlying factors determining the value of the parameter. Two important examples of distributed models are those used for weather prediction and climate models.

Models used for real-time weather forecasting are distributed models. The same models may be used to evaluate historical data or predict how weather would change if certain parameters changed – sensitivity analysis. If the statistical characteristics of the parameters are known, Monte Carlo techniques might be used to provide statistical evaluations of the impacts of changing parameters.

Climate models are distributed models. These are discussed extensively in Chapter 17.

.

3.5 Information support

Key web sites:

1. 'The science of weather forecasting: what it takes and why it is so hard to get right' by Victor Ongoma, February 1, 2022. https://theconversation.com/the-science-of-weather-forecasting-what-it-takes-and-why-its-so-hard-to-get-right-175740?utm_medium=email&utm_campaign=Latest%20from%20The%20Conversation%20for%20February%202%202022&utm_content=Latest%20from%20The%20Conversation%20for%20February%202%202022+CID_db2ba60ce0fe42e6d23e6b0031d75f98&utm_source=campaign_monitor_ca&utm_term=The%20science%20of%20weather%20forecasting%20what%20it%20takes%20and%20why%20its%20so%20hard%20to%20get%20right

2. World Meteorological Organization. https://public.wmo.int/en

3. State of the Global Climate 2022. https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate

4. WMO Integrated Global Observing System. https://public.wmo.int/en/programmes/wigos

5. WMO Catalogue for Climate Data. https://climatedata-catalogue.wmo.int/

6. Government of Canada historical data. https://climate.weather.gc.ca/historical_data/search_historic_data_e.html