

ORCHESTRATEUR

METEOROLOGY: UNDERSTANDING PHENOMENA, READING FORECASTS AND MAKING CAREFUL DECISIONS

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METEOROLOGY: UNDERSTANDING PHENOMENA, READING FORECASTS AND MAKING CAREFUL DECISIONS

An original Lafayette Digital Products guide, translated into English from the French manuscript written on 11 October 2026, for students completing upper secondary school. The French text was drafted with the help of Codex, OpenAI's artificial intelligence assistant, then reviewed and corrected. This guide supports courses and documents from specialist services; it is not an official educational certification. Numerical examples, people and situations identified as fictional are educational creations. References are used to check concepts or historical information; no third-party book is condensed in full.

Each chapter combines analysis, original examples, exercises with worked answers, common mistakes and a revision sheet. Attempt the exercises before reading their answers, then explain in your own words why each answer is justified. The worked answers provide reasoned approaches, rather than a guaranteed grade or an official examination marking scheme.

This offline guide provides no current forecast or warning. For any activity exposed to weather hazards, consult dated information from meteorological services and instructions from the appropriate authorities. It offers no diagnosis or medical procedure. Orchestrateur is not a medical device; consult a healthcare professional when needed and, in an emergency, call the official local emergency number.

CHAPTER 1 - WEATHER, CLIMATE AND MEASUREMENT: SPATIAL SCALES, TIMESCALES AND INSTRUMENTS

1. What a weather observation describes

Saying that the weather is bad combines an observation with a judgement. One person wants rain for a garden; another wants dry skies for a journey. To understand a phenomenon, we must first describe quantities: air temperature, pressure, humidity, wind, precipitation amount and visibility. Here, weather means the state of the atmosphere and its development at a particular scale. Climate describes conditions statistically over long periods, through averages, distributions and variations. A cold spell therefore does not, by itself, establish a climate trend; a climate average does not predict the weather on a particular day.

The atmosphere is a physical medium. It contains mainly gases, but also particles and sometimes droplets or crystals. Water vapour is an invisible gas; a visible cloud is not simply a store of vapour that we can see. Later chapters will examine this distinction more closely. Already, it shows why everyday words can conceal different physical states. An apparently clear sky does not mean that no water is present, while a cloud does not guarantee rain reaching the ground.

A measurement is complete only when it specifies a quantity, a unit, a place, an instant or duration, and a method. Writing “temperature: 18” is insufficient. We must specify 18 degrees Celsius, measured under which conditions, at what time and in which place. Twelve millimetres of rain over one hour does not describe the same average intensity as twelve millimetres over a day. An average wind speed over a specified period is not the

same as a maximum gust. Knowledge begins with a description that makes comparison possible.

2. Different scales change the question

A shower may affect one neighbourhood and miss a station a few kilometres away. A depression may organise the weather over a large region for several days. A climate series may cover several decades. These scales are not interchangeable. When asking whether a forecast is correct, we must specify the area, period and event being assessed. A forecast of possible showers across a district does not assert that rain will fall in every street throughout the day.

Spatial scale concerns the extent of a phenomenon and the resolution of the information. Timescale concerns its duration, the frequency of observations and a forecast's lead time. A measurement at one point samples the environment; it does not reproduce everything happening nearby. A satellite image covers a large area but does not automatically replace a ground measurement. Hourly readings may miss a very brief variation. Instruments therefore complement one another because they do not observe exactly the same things.

Fictional scenario: two students place one thermometer in a courtyard and another near a sunlit wall. The first reads 21 degrees, the second 29 degrees. They conclude that one must be broken. This conclusion goes beyond the observations. Incoming radiation, ventilation, proximity to the wall and the time allowed for the instruments to settle may explain the difference. To compare the devices, they must first be placed in comparable conditions. Here, disagreement between two numbers raises a question about method before it proves a fault.

3. From an instrument to a data point

A sensor converts a property of its surroundings into a signal that can be read or recorded. A thermometer measures its own temperature after exchanging energy with its environment; we want this temperature to represent the air temperature appropriately. A barometer responds to pressure. A rain gauge collects water over a known area. An anemometer measures local motion. None of these instruments directly describes the entire atmosphere.

Resolution is the smallest change a device can display or distinguish. A detailed display does not guarantee accuracy. A screen showing 20.137 degrees may be affected by a bias greater than its final displayed digits. Calibration compares an instrument with a reference under specified conditions. Uncertainty expresses limited knowledge of the result; it does not mean that every measurement is unusable. We must learn to retain only the digits and conclusions that the method can actually support.

Bias persistently shifts results in one direction. Random variability can produce deviations in several directions. Repeating a measurement helps us investigate that variability, but does not necessarily remove a shared bias. Ten readings from an instrument with unsuitable exposure may be very close to one another while all representing the intended air temperature poorly. Repetition is useful when we understand what it checks. It does not replace control of the measurement conditions.

4. Rainfall depth as an example of a quantity

Precipitation depth corresponds to a volume spread over an area. One millimetre of water over one square metre represents one litre. We can demonstrate this: one millimetre equals 0.001 metre; multiplied by one square metre, it gives 0.001 cubic metre, or one litre. This calculation establishes a geometrical equivalence. It does not say that every square metre of a region receives exactly the same amount, or that all the water stays in place after rainfall.

In a fictional scenario, a horizontal area of 4 square metres uniformly receives 7 millimetres of rain. The corresponding volume is 4 × 7 = 28 litres. For a roof, we must also distinguish the relevant collection area, losses, flows and the system's capacity. The theoretical number guarantees no available volume. The same care applies to runoff: soil, slopes and the initial conditions alter how the ground responds.

An average intensity is calculated by dividing a depth by a duration. Twelve millimetres in two hours corresponds to an average of 6 millimetres per hour. Almost all the rain could have fallen within ten minutes. The average therefore does not recover the instantaneous maximum or local impacts. A safety bulletin must be read together with its information about duration, distribution and possible consequences, rather than only its total.

5. Direct measurements and indirect observations

A station provides local measurements according to its location and sensors. A weather balloon explores a vertical profile as it moves. Radar analyses signals reflected by particles and produces estimates that require interpretation. A satellite observes radiation; physical methods are then used to infer certain properties of the environment. Indirect observation does not mean invention. It means that we need to understand the relationship between the received signal and the quantity being investigated.

A coloured image is already a representation. Its colours may correspond to value classes rather than the colours a human observer would see. Always read the legend, production time, area covered and quantity represented. A cloud image is not sufficient to establish that rain is falling at ground level. Radar may detect precipitation aloft, some of which evaporates before reaching the ground. The absence of a measurement in an area is not evidence that no phenomenon is occurring there.

In its introduction to observations, the Met Office states: “Meteorological observations are essential for understanding and predicting weather and climate.” This short eleven-word quotation places data in context; it does not say that one instrument predicts everything. The examples and reasoning in this chapter are original. The reference is used to check distinctions between observation types, without reproducing detailed descriptions of its networks or operational values.

6. Missing data and changes in method

A series of readings sometimes contains gaps. Replacing a missing value with zero turns a lack of information into a measurement and distorts the results. An explicit indication that data are missing must be retained. If a value is estimated, the estimate must remain distinguishable from an observation. In an educational notebook, an honest incomplete series is preferable to a series filled with imaginary numbers.

Moving a station, replacing an instrument or changing the surroundings may alter a series. A comparison before and after such changes therefore needs to distinguish changes in the atmosphere from changes in measurement. This does not mean that long series have no value. It explains the checking required before interpreting them in climate terms. A courtyard gradually surrounded by buildings no longer represents exactly the same environment as an open courtyard.

Statistics describe the available series according to chosen rules. An average may conceal extremes; a median may conceal their importance for an exposed activity. A frequency can be interpreted only if the events have been defined. Counting rainy days requires a threshold and a period. Changing the threshold midway through a comparison changes the result's meaning. Scientific honesty requires these choices to be visible.

7. An original educational investigation

Imagine that you want to compare two places: a garden and a paved square. The question “where is it warmer?” must become more precise. Do you want to compare air temperature in the shade, the temperature of a surface or a person's thermal sensation? These are not three names for the same quantity. An exposed surface may be hot while a correctly shielded air sensor indicates a different value. A sensation also depends on wind, radiation and individual factors.

A reasonable method for a school exercise is to choose one quantity, use comparable instruments, record the time and conditions, then repeat the comparison without claiming to have produced a full climatological study. Results should be presented as limited local observations. You can propose a hypothesis about the role of materials and shade, but must acknowledge uncontrolled factors. A carefully bounded hypothesis teaches more than a general conclusion about all cities.

The notebook can contain four columns: what was observed, how it was measured, the proposed interpretation and what remains uncertain. This separation prevents an impression from immediately becoming an explanation. If you record “dark cloud”, do not automatically replace that observation with “imminent thunderstorm”. A possible interpretation must remain an interpretation. A real activity requires updated information from the responsible services, even when an exercise has been carried out correctly.

8. Progressive exercises and worked answers

Exercise 1 - Completing a data point. A notebook says “wind: 30”. List the missing information and propose a complete fictional entry.

Possible answer: at minimum, the unit, type of value, direction if measured, place, time and method are missing. An educational entry might read “fictional mean wind speed of 30 km/h, from the west, over the period indicated by the instrument, at point A, at 14:00”. This is not a real observation. It shows why a numerical value alone supports neither a rigorous comparison nor a safety decision.

Exercise 2 - Converting a depth. A fictional horizontal area of 3 square metres uniformly receives 8 millimetres of rain. Calculate the corresponding geometrical volume and give two practical limitations.

Answer: 1 millimetre over 1 square metre corresponds to 1 litre, so the volume is 3 × 8 = 24 litres. Rainfall may not be uniform; losses and runoff may prevent complete collection. The calculation does not establish a quantity of drinking water and supports no conclusion about health. The units and the meaning of the result must accompany the calculation.

Exercise 3 - Examining an average. A shower delivers 15 millimetres in thirty minutes. What average intensity does this give in millimetres per hour? Can we infer the maximum during one minute?

Answer: thirty minutes is half an hour, so 15 / 0.5 = 30 millimetres per hour. The maximum over one minute is unknown. A steady distribution and a sequence of strong variations may have the same average. Do not turn an average quantity into an instantaneous measurement. This distinction is essential when interpreting the effects of precipitation on the ground.

Exercise 4 - Separating weather from climate. A city experiences a day colder than the average for a month. A comment concludes that the climate is not changing. Analyse the inference without discussing a real climate series here.

Answer: a daily observation and a long-term statistical development concern different scales. Values below an average can occur in a distribution whose average is increasing. A sufficiently long, checked series must be studied to address the climate question. The exercise refutes an inference based on one day; it calculates no real trend and replaces no specialist analysis.

Exercise 5 - Designing a comparison. Two thermometers give different values. Propose three checks before declaring one faulty, then explain what repetition can and cannot establish.

Answer: compare their exposure to radiation, ventilation and settling time; also examine their resolution and calibration reference. Temporarily placing them in comparable conditions may help identify an instrumental difference, provided that this respects their intended use. Repetition provides information about variability, but does not automatically remove a shared bias. The conclusion must remain proportionate to the checks performed.

9. Common mistakes and revision sheet

Common mistakes include confusing a displayed value with an exact value, surface temperature with air temperature, gusts with mean wind speed, and an image with an observation that can be interpreted directly. Another mistake is assigning zero to missing data. Climate conclusions drawn from a single day and practical decisions based on an old map also occur. These confusions are corrected by returning to the quantity, unit, scale and method.

Revision sheet: a data point must have a location and date; an average does not describe all extremes; a measurement at one point is not a complete map; an indirect observation requires an interpretative model. One millimetre of water over one square metre equals one litre. Climate describes distributions and their changes; weather describes atmospheric situations over shorter

scales. Any forecast used for a real activity must be updated and appropriate to its area.

To revise, explain why two different numbers can be compatible with two correctly conducted measurements. Then construct a situation in which the difference really does reveal an instrumental problem. The purpose is not to defend every instrument: it is to understand which checks make a conclusion possible.

Sources and provenance: NOAA, physical introduction to the atmosphere, https://www.noaa.gov/jetstream/atmosphere ; Met Office, Types of observations, https://weather.metoffice.gov.uk/learn-about/how-forecasts-are-made/observations, the short quotation above and distinctions between observation families. Pages consulted for the French manuscript on 11 October 2026. Unit equivalences, scenarios, exercises and worked answers written by LFDP. No current map, operational forecast, third-party image or measurement series reproduced.

CHAPTER 2 - TEMPERATURE AND ENERGY: RADIATION, CONDUCTION, CONVECTION AND ENERGY BALANCE

1. Temperature and energy are different things

A small amount of hot water and a large lukewarm tank may have different temperatures while storing very different amounts of thermal energy. Temperature describes a state; transferred energy describes what passes from one system to another or is transformed. To reason about meteorology, we must specify the system: a patch of ground, a volume of air, a layer of atmosphere, or the entire Earth-atmosphere system. Without this choice, we may mix up a local exchange with a global balance.

Here, heat means energy transferred because of a temperature difference. It is not a substance contained in air like water in a bottle. At a microscopic level, temperature is related to the motion of the constituents; in this course, we mainly use relationships between macroscopic measurements. Temperature in degrees Celsius is suitable for everyday life. Physical calculations involving absolute temperature use kelvins: T in kelvins = temperature in degrees Celsius + 273.15. A change of one kelvin corresponds to a change of one degree Celsius.

One difference is essential: going from 10 to 20 degrees Celsius does not mean doubling the absolute temperature. It means going from 283.15 to 293.15 kelvins. Using degrees Celsius directly in a formula proportional to absolute temperature can cause a major error. Choosing units is therefore not a minor matter of presentation; it is part of the physical meaning of the calculation.

2. Distinguishing three transfer mechanisms

Conduction transfers energy through matter without necessarily requiring bulk movement of the medium. Neighbouring regions in the ground exchange energy in this way. Convection involves the movement of a fluid, such as air carrying energy from one region to another. Radiation carries energy in electromagnetic form and can travel through a vacuum. These mechanisms can act simultaneously. Identifying one does not make them three mutually exclusive causes.

In a fictional scene, a slab receives solar radiation, exchanges energy with the ground beneath it and warms the air in contact with it. Air movement then brings fresh air into contact with the slab. Radiation explains an energy input; conduction operates within matter; air movements contribute to transport. Merely saying that the sun heats things does not yet explain why two neighbouring surfaces develop differently or why wind changes their temperature.

Natural convection depends, among other things, on density differences and the medium's stratification. A parcel of air less dense than its surroundings may rise because of buoyancy. This does not mean that all warm air rises indefinitely or carries only its heat without changing its state. Ambient pressure, mixing and vertical conditions matter. The chapter on clouds will examine cooling associated with ascent, distinguishing it from a simple loss of heat through contact.

3. Absorption, reflection and emission

When radiation reaches a surface, some may be reflected, some absorbed and, sometimes, some transmitted. Albedo is a reflected fraction defined for specified conditions and a specified range of radiation. A value of 0.30 means that 30% of the flux under consideration is reflected. It does not mean that the surface necessarily remains cold: its complete energy balance and properties must be examined.

An entirely fictional numerical example uses two surfaces each receiving 500 watts per square metre. The first reflects 20% and, in this model without transmission, absorbs 400 watts per square metre. The second reflects 60% and absorbs 200 watts per square metre. The absorption difference is 200 watts per square metre. To conclude that their temperatures differ, we must also know their heat capacities, losses, available water and surroundings. Absorption alone is not a temperature.

Objects on Earth also emit thermal radiation. This does not disappear at night; it is precisely one reason why a surface can lose energy without sunlight. Emission depends on temperature and surface properties. Visible colour does not reveal every characteristic in the infrared. Claiming that a dark object always emits more in every wavelength range would therefore be too general. We must distinguish absorption of solar radiation from thermal emission.

4. Constructing a balance rather than a single explanation

An energy balance compares inputs, outputs and the change in storage. In simplified form, change in energy = energy received minus energy transferred out. If inputs exceed outputs, the system accumulates energy; if they are smaller, it loses energy. This accounting principle does not supply every flux: it shows how to relate them when measurements or assumptions are available.

NASA uses the expression “Energy leaves the surface” in its explanation of Earth's energy budget. This short four-word quotation simply reminds us to examine outputs as well as inputs. The numbers in its illustrations are not reproduced here. In our educational models, numbers are fictional and omitted exchanges are explicitly stated. This approach prevents an exercise from being presented as a current measurement of the climate system.

Fictional scenario: a surface receives total inputs of 420 watts per square metre and transfers total outputs of 390 watts per square metre for ten minutes, assumed constant. The net flux is +30 watts per square metre. Over 600 seconds, the accumulation is 30 × 600 = 18,000 joules per square metre. We cannot immediately convert this result into degrees without knowing the mass involved and its heat capacity, or checking that no other transformations occur.

5. Heat capacity and thermal inertia

Heat capacity indicates the energy needed to change a system's temperature under specified conditions. For a mass m of a substance whose specific heat capacity c is approximately constant, with no change of state, Q = m × c × temperature change. Q is expressed in joules when m is in kilograms, c in joules per kilogram per kelvin, and the change in kelvins. The formula describes a limited model; it cannot be applied without care to a transformation involving evaporation or melting.

In a fictional exercise, 2 kilograms of water are modelled with c = 4,200 joules per kilogram per kelvin. Warming them by 3 degrees requires Q = 2 × 4,200 × 3 = 25,200 joules, if other exchanges are ignored. A constant net power of 100 watts would supply this energy in 252 seconds. This result follows from the assumptions; it does not describe a real device, whose net power and losses may vary.

Thermal inertia explains why a medium does not respond instantaneously to a change in energy input. A large reservoir may continue transferring energy out after incoming radiation decreases. Different materials and thicknesses do not necessarily respond in the same way. Oceans and soils therefore participate in different rhythms, but a general statement is insufficient to predict a local temperature. Transport and changes of state must also be studied.

6. Evaporation and latent energy

A change of state may require energy without producing the temperature change predicted by the preceding formula. Evaporation requires an energy input; condensation releases energy to the surroundings. This energy contributes to atmospheric exchanges. The term latent does not mean magical or inaccessible: it distinguishes a transfer linked to a change of state from sensible warming within the model being used.

Consider a fictional surface receiving the same available net flux under two conditions. In the first, water can evaporate; in the second, the surface is dry and this transfer pathway is reduced. Temperature changes may differ because the distribution of energy differs. An exact temperature cannot automatically be inferred simply from whether a surface is wet or dry. Wind, water supply and other exchanges change this distribution.

This explanation helps us understand why a temperature observation is insufficient to describe all the energy exchanged. A system may receive energy and use some of it for a change of state. Conversely, droplet formation is accompanied by an energy release that influences the surrounding medium. Clouds are therefore more than shapes in the sky: they participate in physical transformations that a model must represent.

7. Radiative equilibrium, climate and local variability

A long-term global equilibrium means that average inputs and outputs approximately balance. It requires neither a uniform temperature nor an absence of local variations. Different regions receive and transfer different amounts of energy; atmospheric and oceanic circulations redistribute it. A surface warming during an afternoon does not prove that the whole planet is simultaneously accumulating a proportionate amount of energy.

Gases and clouds interact with radiation according to wavelength. The atmospheric greenhouse mechanism must not be equated completely with that of a garden greenhouse, where other exchanges are also modified. The term remains useful if we specify that it concerns radiative absorption and emission in the atmosphere. This chapter calculates no climate projection and does not turn the mechanism into a single explanation of tomorrow's weather.

Cloud cover may alter solar inputs and infrared exchanges. Its net effect depends on conditions; a rule stating that clouds always warm or always cool would be inadequate. The same process can have different consequences depending on time, altitude, thickness and other components of the balance. This limitation invites us to ask the right question, rather than abandon physical explanations.

8. Progressive exercises with worked answers

Exercise 1 - Units. Convert 12 degrees Celsius into kelvins. Does a temperature change of 4 degrees Celsius correspond to a change of 277.15 kelvins?

Answer: 12 + 273.15 = 285.15 kelvins. A change of 4 degrees Celsius corresponds to 4 kelvins, because the offset between the scales disappears in the difference. Adding 273.15 to a change would be an error. Distinguish a temperature value from the difference between two temperatures before choosing the operation.

Exercise 2 - Fictional albedo. A flux of 600 watts per square metre reaches an opaque surface whose albedo for this flux is 0.25. Calculate the reflected and absorbed portions. Can its temperature be inferred?

Answer: the reflected portion is 600 × 0.25 = 150 watts per square metre; the absorbed portion is 450 watts per square metre. The temperature is undetermined: outputs, heat capacity and transformations are missing. Even an exact numerical calculation may therefore produce partial information. Name that information instead of giving it a scope it does not have.

Exercise 3 - Storage. A fictional system has a net flux of −20 watts per square metre for five minutes. Calculate its energy change per unit area and interpret the sign.

Answer: five minutes equals 300 seconds, so −20 × 300 = −6,000 joules per square metre. The negative sign indicates a net loss under the stated convention. It does not directly supply a temperature decrease in degrees. A sign convention must remain the same throughout the calculation; a sign is not a decoration added after obtaining the result.

Exercise 4 - Simplified heating. A fictional volume of air has a mass of 3 kilograms, with c assumed equal to 1,000 joules per kilogram per kelvin. It receives 9,000 joules with no other exchange or change in mass. What change does the model give? State two reasons why the real atmosphere is more complex.

Answer: change = Q / (m × c) = 9,000 / 3,000 = 3 kelvins, or 3 degrees Celsius. In the atmosphere, movement and mixing alter the system; pressure and water transformations may also matter. The result is valid under the assumptions, rather than a local forecast. Identifying the missing conditions is part of the scientific answer.

Exercise 5 - Reasoning. Someone claims that wind cannot influence a sunlit surface because the sun continues to radiate. Construct an answer using an energy balance.

Possible answer: radiation describes an input, while wind may change exchanges with the air and evaporation. An unchanged input does not require an unchanged balance. All fluxes would need to be known to predict the change. This answer does not claim that every wind always has the same consequence; it identifies why the initial argument is incomplete.

9. Common mistakes and revision sheet

The main mistakes are confusing temperature with energy, flux in watts with energy in joules, absolute temperature with a difference, and solar absorption with infrared emission. Another mistake is explaining every change through one mechanism without defining the system. To correct yourself, write down the inputs, outputs and storage before calculating. Then check units and assumptions.

Revision sheet: conduction = transfer through matter; convection = transfer associated with fluid motion; radiation = electromagnetic transfer. Energy = power × duration when power is constant. A positive balance indicates accumulation, not necessarily warming that can be calculated directly. Q = m × c × temperature change requires a valid domain of application. A water transformation may involve latent energy. Average global equilibrium eliminates neither contrasts nor local variations.

Sources and provenance: NOAA, The Transfer of Heat Energy, https://www.noaa.gov/jetstream/atmosphere/transfer-of-heat-energy, used to check the three mechanisms; NASA, Climate and Earth's Energy Budget, https://science.nasa.gov/earth/earth-observatory/climate-and-earths-energy-budget/, used to check the distinction between fluxes and balance, with the identified short quotation. Consulted for the French manuscript on 11 October 2026. No third-party graph or Earth energy-budget figure reproduced. All exercise values are fictional and the educational explanations are LFDP originals.

CHAPTER 3 - PRESSURE, DENSITY AND WIND: GRADIENTS AND ATMOSPHERIC CIRCULATION

1. Pressure as force distributed over an area

Pressure is force divided by an area in the situation being considered. Its SI unit is the pascal: one pascal corresponds to one newton per square metre. In meteorology, the hectopascal is convenient: 1 hPa = 100 Pa. A difference of 6 hPa therefore corresponds to 600 Pa. This conversion does not change the phenomenon; it changes the unit used to describe it. An isolated value still requires an altitude, date and measurement method.

At a microscopic scale, the constituents of a gas move and interact with surfaces. At an atmospheric scale, the weight of the layers above contributes to the observed pressure. These descriptions complement one another. Pressure does not act only downwards; the medium exerts actions in different directions. Air should not be imagined as an immobile stack of solid plates. It is a fluid whose movements change the distribution of mass.

In a fictional exercise, a pressure difference of 500 Pa applies over an area of 0.2 square metre. Their product gives a force of 100 newtons in the model. This calculation does not automatically describe the force acting on a person or building: the pressures on each side, directions and geometry would need to be known. A correctly calculated number can become misleading if the object to which it applies is silently changed.

2. Altitude and comparing stations

Pressure generally decreases as we ascend through the atmosphere because less air lies above us. The decrease is not a universal constant slope over the whole altitude range. Temperature, density and vertical structure matter. A local educational rule must not be extrapolated without specifying its validity. To compare two stations at different heights, we need to know whether the values are pressures actually measured at the stations or values conventionally reduced to the same reference level.

Fictional scenario: a station in a valley reads 1,010 hPa and a station on higher ground reads 930 hPa. We cannot immediately conclude that a local depression of 80 hPa lies over the summit. The altitude difference may explain much of the difference. A synoptic chart uses conventions that allow places to be compared; interpreting them requires the legend and method. Confusing station values with adjusted values leads to invented gradients.

Adjustment to sea level does not mean physically moving the barometer. It is a calculation that depends on physical assumptions. Being calculated does not make the value useless: it supplies a common reference. Nevertheless, it reminds us that data may be raw measurements or derived quantities. A reading intended to understand height and one intended to compare weather systems do not answer exactly the same question.

3. Density, temperature and composition

Mass density relates mass to volume. An air density of 1.2 kilograms per cubic metre means that the volume being studied contains that mass under the stated conditions. It varies with pressure, temperature and composition. The ideal-gas model relates these quantities through an equation; for dry air within a suitable range, we write p = rho × R × T, with T in kelvins and an appropriate constant R.

At equal pressure and composition, increasing temperature reduces density in this model. The equal conditions must be stated: heating a gas in a rigid sealed container does not reproduce expansion at constant pressure. A statement such as warm air is always less dense therefore lacks precision if the other quantities change. Meteorology uses comparisons under specified conditions, rather than an adjective replacing every condition.

Original example: two parcels of dry air are modelled at the same pressure, one at 283 K and the other at 293 K. Their density ratio, rho warm / rho cold, is 283 / 293, approximately 0.966. The warm parcel is therefore about 3.4% less dense in this model. The calculation alone does not establish a vertical trajectory: information about the surroundings, mixing and constraints on movement is missing. Humidity also introduces a difference in composition ignored by the dry-air model.

4. The pressure gradient

A gradient describes how a quantity changes in space and, in vector form, the direction of its greatest increase. As a first approach, we can compare a pressure difference with a distance. Two areas separated by a short distance with the same pressure difference as two distant areas do not produce the same change per unit length. This distribution, rather than simply the numerical pressure at a depression's centre, contributes to the acceleration of air.

The pressure-gradient force pushes air towards lower pressure. This does not mean that real wind always follows a straight line from the maximum to the minimum. In Earth's reference frame, rotation, friction, curvature and other components of motion matter. An initial explanation can isolate one force; it becomes false when presented as the entire real trajectory.

On a chart, an isobar connects points of equal pressure under the convention used. Closely spaced isobars may indicate a stronger horizontal gradient, when contour intervals and scales are comparable. Comparing two charts directly when their intervals differ can mislead. A chart with little detail does not necessarily mean an atmosphere without contrasts. Read the graphical scale, represented altitude and time before drawing a conclusion.

5. Calculating two fictional gradients

In the first situation, a difference of 8 hPa extends over 400 kilometres. This corresponds to 800 Pa over 400,000 metres, an average of 0.002 Pa per metre. In the second, the same difference extends over 100 kilometres: 800 / 100,000 = 0.008 Pa per metre. The second average gradient is four times greater. This calculation compares two idealised distributions, rather than two wind forecasts.

If movement is reduced to the gradient's action on air of uniform density rho, an acceleration estimate would be gradient / rho. This expression is enough to check the dimensions: Pa per metre divided by kilograms per cubic metre gives metres per second squared. Real wind cannot, however, be obtained by multiplying this constant acceleration by an arbitrary duration; other forces and changes in the gradient prevent that extrapolation.

This limitation illustrates a general modelling rule. A formula describing an instantaneous effect under assumptions does not automatically provide the complete development. Predicting movement requires an initial state, compatible relationships and changes in conditions. Knowledge of a mechanism is necessary, but does not replace every piece of information required for a forecast.

6. Earth's rotation and friction

In Earth's rotating reference frame, the Coriolis effect contributes to the description of large-scale movements. It deflects motion to its right in the Northern Hemisphere and to its left in the Southern Hemisphere, under the usual conventions for horizontal motion. It is not a force that, by itself, creates wind from stationary air. Its importance depends particularly on scale and latitude; it is not identical for a synoptic circulation and a small eddy near an obstacle.

Away from the ground and under suitable assumptions, an approximate balance may develop between the Coriolis effect and the pressure gradient; wind may then be close to parallel to the isobars. Near the ground, friction alters this balance and motion may cross the isobars more strongly. These descriptions are models for understanding, rather than rules for navigation. Terrain, buildings and local circulations may cause substantial departures.

Friction and roughness do not necessarily make all wind weak. They alter speeds, directions and turbulence. A narrow passage may channel a flow; an obstacle may create local variations. Inferring practical safety from one average value would therefore be inadequate. Gusts and the activity's particular conditions must be investigated using updated information.

7. Global circulations and a historical reference

The unequal distribution of energy, Earth's rotation and surface properties contribute to atmospheric circulations. Diagrams of global cells provide a useful average model; they do not represent every system at every instant. Seasons and differences between continents and oceans shift or alter structures. A regular drawing on a globe is a simplification that must be interpreted at its own scale.

NOAA notes that George Hadley proposed an explanation of circulation associated with equatorial regions and winds in 1735. This historical reference shows how a model can organise a question and subsequently be developed and corrected. It does not give an old diagram the status of a current forecast. The details of that history and NOAA's figures are not reproduced; our point concerns the difference between a circulation model and an observed state.

A depression is not simply universal bad weather, nor an anticyclone guaranteed fine weather. Vertical movement, humidity, season and local conditions alter the associated phenomena. High pressure may accompany fog or other troublesome conditions; a point near low pressure may experience a temporarily calm period. These possibilities encourage us to read a complete bulletin, rather than reduce all meteorology to a barometric value.

8. Progressive exercises with worked answers

Exercise 1 - Conversion. Convert 1,005 hPa into pascals, then a difference of 3.5 hPa. Why must absolute pressure and a difference not be interchanged when calculating a net force?

Answer: 1,005 hPa = 100,500 Pa; 3.5 hPa = 350 Pa. A net action on a surface depends on the actions on either side and their direction. Using an absolute pressure instead of the difference may overestimate the result in a model where both sides experience similar pressures. Identify the relevant quantity before multiplying.

Exercise 2 - Altitude. Two stations at different altitudes display different pressures. What information would you request before comparing the weather situation?

Answer: altitude, whether pressure is measured at the station or adjusted, the adjustment convention, time and measurement quality. A raw difference may be mainly related to height. Comparable data would be required to discuss a horizontal gradient. This answer does not calculate an adjustment; it shows why inventing one without assumptions would be incorrect.

Exercise 3 - Gradient. One fictional chart shows a difference of 5 hPa over 250 kilometres. Another shows 5 hPa over 50 kilometres. Calculate the average gradients and their ratio.

Answer: 500 Pa / 250,000 m = 0.002 Pa/m; 500 Pa / 50,000 m = 0.010 Pa/m. The second is five times the first. These values do not directly give a wind speed; other forces and initial conditions are missing. The ratio answers the question without fabricating a forecast.

Exercise 4 - Density. At equal pressure and composition, a model gives T cold = 280 K and T warm = 300 K. What ratio rho warm / rho cold is obtained? What cannot be concluded from it?

Answer: 280 / 300 = approximately 0.933. Density in the warm case is about 6.7% lower in this model. Neither vertical speed, the duration of ascent nor mixing is known. Comparing densities may contribute to an explanation of buoyancy; it is not a complete circulation calculation.

Exercise 5 - Criticising a rule. Someone claims that isobars always show the exact direction of surface wind. Propose a reasoned correction.

Possible answer: isobars describe pressure on a chart; approximately parallel wind may arise under certain large-scale assumptions away from strong ground friction. At the surface, friction, terrain, curvature and local structures alter the direction. The word always exceeds the model's domain. Retain the chart's usefulness without turning it into a direct measurement of every local wind.

9. Common mistakes and revision sheet

Common mistakes confuse pressure with density, altitude with a horizontal gradient, a low-pressure centre with wind speed, and mean wind with gusts. Others apply a constant-pressure model to a fixed-volume container or attribute every eddy to Coriolis. To correct yourself, state the system, conditions held constant and scale. A formula must not circulate without its assumptions.

Revision sheet: 1 hPa = 100 Pa; station pressure depends on altitude; a value reduced to a common level is calculated. A gradient compares a change with a distance. The pressure-gradient force is only one term in the dynamics. Coriolis, friction and the surroundings modify the trajectory. Global diagrams describe average structures and provide no current warning.

Sources and provenance: BIPM, SI Brochure, https://www.bipm.org/en/publications/si-brochure, used to check units; NOAA, Air Pressure, https://www.noaa.gov/jetstream/atmosphere/air-pressure, pressure concepts and station comparisons; NOAA, Global Atmospheric Circulations, https://www.noaa.gov/jetstream/global/global-atmospheric-circulations, the Hadley 1735 reference. Pages consulted for the French manuscript on 11 October 2026. No third-party graph, historical barometric advice or operational value reproduced. Original fictional LFDP calculations and scenarios.

CHAPTER 4 - WATER IN THE ATMOSPHERE: VAPOUR, SATURATION, RELATIVE HUMIDITY AND DEW POINT

1. Three states of water, several quantities

Atmospheric water may be gaseous, liquid or solid. Water vapour is invisible; droplets and crystals may make a cloud visible. The amount of vapour and the presence of a cloud therefore provide different information. A cloudless day may contain vapour; a cloud may exist without producing precipitation at ground level. Confusing these things leads to misinterpretation of humidity measurements.

Absolute humidity expresses a mass of vapour per unit volume, for example in grams per cubic metre. Specific humidity expresses a mass of vapour relative to a mass of moist air. The mixing ratio relates that mass to the mass of dry air. These definitions are close in some cases, but their denominators differ. One quantity must not replace another simply because all concern water in the air. The choice depends on the comparison being sought.

The partial pressure of vapour, denoted e in our model, describes its contribution to the pressure of the gas mixture. Saturation vapour pressure, denoted e_s(T), depends on temperature and on whether the reference is liquid water or ice. Relative humidity compares e with this reference value: RH = 100 × e / e_s(T). The formula immediately shows why relative humidity is not simply an amount of vapour independent of temperature.

2. Saturation is not a full bottle

A familiar image says that warm air can hold more water. This image helps us remember a trend, but risks suggesting that air is a container with a fixed number of spaces. Saturation concerns an equilibrium between phases and the vapour pressure at a given temperature. Water's behaviour does not depend on a mechanical storage capacity like that of a sponge. In this guide, the container image is therefore replaced by a relationship between physical quantities.

At a higher temperature, saturation vapour pressure over liquid water is greater. If e stays the same while e_s increases, their ratio decreases. Relative humidity may therefore fall without the corresponding quantity of vapour having been removed. However, the assumed process must be specified: in a real situation, exchanges of water and changes in volume and pressure may also change e. A relationship between two quantities does not allow us to forget transformations of the system.

Saturation alone does not guarantee rain. NOAA reminds readers of this with the short wording: “does NOT necessarily mean that precipitation will occur”. This eight-word passage concerns the connection between saturation and precipitation; it describes no current situation. Other growth and transport processes are involved before precipitation forms and reaches the ground. These are studied in the next chapter.

3. An original calculation with changing temperature

Our first educational model fixes a partial pressure e = 1.2 kPa. It uses two rounded reference values chosen for the exercise: e_s = 2.4 kPa in state A and e_s = 4.0 kPa in state B, which corresponds to a warmer state. In A, RH = 100 × 1.2 / 2.4 = 50%. In B, RH = 100 × 1.2 / 4.0 = 30%. Partial pressure has been kept identical by assumption, but the relative value has changed.

These numbers are neither an operational table nor a real reading. They isolate the role of the denominator. Someone claiming that B must contain less vapour because 30 is lower than 50 has forgotten that the references differ. Comparing percentages always requires knowing what they refer to. The same mistake appears in many everyday statistics.

A second model compares two fictional places. Place C has e = 0.8 kPa and e_s = 1.0 kPa, giving 80%. Place D has e = 1.6 kPa and e_s = 4.0 kPa, giving 40%. D has a higher partial vapour pressure despite its lower relative humidity. These data alone do not establish an individual's sensation, a surface temperature or a health decision. The calculation demonstrates only the distinction between the chosen absolute quantity and a relative proportion.

4. Dew point

The dew point is the temperature at which cooling air, under the specified conditions, brings it to saturation over liquid water. It therefore links the vapour present with the corresponding saturation temperature. When air temperature is close to the dew point, the distance from that saturation state is small. This does not automatically establish a particular visibility or a time when fog will form.

In a fictional model, a parcel of air cools without losing vapour before saturation, while pressure is maintained. If the reference

value e_s reaches e, RH reaches 100%. Further cooling may lead to condensation under suitable conditions. This statement does not describe every stage in the development of a real air mass: mixing, transport, surfaces and water exchanges may alter the path. A measured dew point is not a self-contained forecast.

Frost point corresponds to a saturation reference over ice. At certain temperatures, the references over water and over ice differ. This qualification prevents 100% from being presented as a single universal boundary without specifying the reference medium. At an introductory level, remember above all that a physical definition must specify its conditions. Finer microphysical phenomena subsequently require more detailed models.

5. Cooling, adding vapour and mixing

Several paths can bring air closer to saturation. Cooling reduces the reference value; adding vapour increases e; mixing parcels of air may produce a situation whose final state depends on exchanges and the balance. All fog must not be attributed to one mechanism. Formation associated with night-time cooling and formation associated with moving air do not have the same conditions.

Fictional scenario: a surface cools during a night and nearby air changes temperature. Relative humidity increases in our model if vapour does not decrease sufficiently to compensate. This does not force the entire region to become foggy: ventilation, the vertical profile and surfaces matter. A local observation may be compatible with several developments. For a real activity, a forecast and updated visibility measurements must be consulted.

Another scenario: an indoor volume of air and an outdoor volume have different temperatures and humidities. Simply taking the arithmetic mean of their percentages does not necessarily give the

mixture's relative humidity. The percentages refer to different temperatures; the relevant physical quantities and balances must first be conserved. This explains why an attractive calculation can be wrong despite correctly performed operations.

6. Measuring humidity without confusing a display with a phenomenon

A hygrometer may provide relative humidity according to its technology and operating conditions. A result depends on the sensor, its temperature, exposure and response time. A value displayed immediately after moving between two environments is not necessarily stable. The instrument's instructions must be consulted and the relevant uncertainty retained. This guide does not authorise turning an amateur sensor into a device for health monitoring.

Units must remain consistent within a formula. If e is given in pascals and e_s in kilopascals, conversion is necessary before division. The ratio is dimensionless and the factor 100 expresses it as a percentage. A relative humidity of 0.65 expressed as a fraction corresponds to 65%, rather than 0.65%. Factor errors can occur before any physical discussion even begins.

Humidity data should be accompanied by a temperature, place and time. To compare two days, it may also be useful to examine the dew point or a suitable measure of vapour amount. No single indicator describes every possible effect of the environment. A measurement must be chosen according to the question, rather than simply because it is available on the screen.

7. Examining competing ideas

First idea: high relative humidity necessarily means a large amount of vapour. Our second calculation shows the limitation of this claim. Two relative values can be compared as amounts only when the relevant references are known. A correct reformulation must specify temperature and the quantity used to describe vapour.

Second idea: once air is saturated, rain is certain. Saturation establishes a local state relative to a reference, rather than complete precipitation. Clouds, particle growth, currents and the path to the ground matter. We must distinguish a condition that may contribute to a phenomenon from a sufficient condition for the entire outcome.

Third idea: a comfort indicator describes universal safety. Information about humidity and temperature may help us understand an environment, but a person's situation also depends on their activity and many other factors. This guide produces no individual medical assessment. Health instructions and professional advice must remain distinct from atmospheric physics exercises. A clear boundary improves the course's usefulness rather than reducing it.

8. Progressive exercises with worked answers

Exercise 1 - Ratios and units. A model supplies e = 900 Pa and e_s = 1.8 kPa. Calculate RH and name the necessary conversion.

Answer: 1.8 kPa = 1,800 Pa; RH = 100 × 900 / 1,800 = 50%. Dividing 900 directly by 1.8 without matching units would produce an absurd result. An order-of-magnitude check complements the calculation: in the model, e is half the reference, so the expected result is half of 100%.

Exercise 2 - Fictional warming. A parcel of air maintains e = 1.0 kPa. The reference changes from 2.0 to 2.5 kPa. Calculate the two relative humidities. What statement about vapour is unjustified?

Answer: 50%, then 40%. The fall in percentage does not demonstrate a decrease in e here, since e was kept constant. This model must also not become a rule for every real warming process: if the system exchanges water or changes other conditions, e may vary. The assumptions form part of the result.

Exercise 3 - Comparing two places. At one fictional place, e = 0.6 kPa and e_s = 0.8 kPa; at the other, e = 1.2 kPa and e_s = 3.0 kPa. Which place has higher RH? Which has higher e?

Answer: the first has 75%, the second 40%. Yet partial vapour pressure is higher at the second. This divergence is precisely the point of the exercise. It requires no judgement about a sensation or hazard. A good answer retains the quantity's name instead of vaguely saying that one is more humid.

Exercise 4 - Dew point. One fictional measurement reports air temperature of 14 degrees and dew point of 13 degrees. Another reports 24 degrees and a dew point of 13 degrees. What can be compared, and what cannot be announced?

Answer: the first state has a smaller gap between temperature and dew point, and is therefore closer to saturation under the defining conditions. Neither a time when rain will fall nor a precise visibility can be announced. A development over time, a place and other information would be needed. The numbers support a conceptual comparison rather than a real forecast.

Exercise 5 - Reasoning. Someone calculates a mixture's humidity by averaging 20% and 80%, with no other data. Explain why 50% is not necessarily the correct answer.

Answer: the percentages may refer to different temperatures, pressures and masses. Their average does not directly conserve a physical quantity of vapour or an energy balance. Masses, initial states and the mixing method must be specified. In some special cases an average may coincide with the result; that coincidence does not justify the general method.

Exercise 6 - Reading a conclusion. “The sensor shows 100%, so rain will begin.” Reformulate the only information obtained and propose two relevant additional pieces of information.

Answer: the sensor indicates relative humidity corresponding to saturation under its measurement conditions, with its limitations and reference. Information about the vertical profile, clouds and atmospheric development could be sought; a real decision still requires an updated bulletin. The exercise provides no guaranteed amateur forecasting procedure.

9. Common mistakes and revision sheet

Common mistakes include seeing vapour, confusing RH with the probability of rain, comparing percentages without temperatures, averaging different references and ignoring a sensor's response time. Another mistake links saturation with certain precipitation. To correct them, write the quantity, unit and denominator before interpreting the result.

Revision sheet: invisible vapour; distinct droplets and crystals; RH = 100 × e / e_s(T); dew point = saturation temperature reached under the stated conditions. A percentage can change without any decrease in e. Saturation is not guaranteed rain. A local measurement replaces neither a dated forecast nor current safety instructions. Numerical examples remain models, rather than a table to use for an exposed activity.

Sources and provenance: NOAA/NWS, Discussion on Humidity, https://www.weather.gov/lmk/humidity, used to check the relationship between temperature, relative humidity and saturation, with the identified short quotation; NOAA/NWS, Dew Point vs Humidity, https://www.weather.gov/arx/why_dewpoint_vs_humidity, used to check the definition of dew point. Consulted for the French manuscript on 11 October 2026. No third-party comfort table, current data or measurement series reproduced. Original LFDP ratio analyses, examples and worked answers.

CHAPTER 5 - CLOUDS AND PRECIPITATION: CONDENSATION, CRYSTALS AND SIMPLIFIED MICROPHYSICS

1. A visible cloud is not a block of vapour

A visible cloud consists of small water droplets, ice crystals or both, depending on its conditions. Vapour remains an invisible gaseous phase. This distinction explains why a cloud's visibility does not directly give the atmosphere's total amount of vapour. Particles scatter light; their size and number, the medium's thickness and the lighting alter its appearance. A dark cloud is not simply filled with a darker substance.

Condensation transforms vapour into liquid water; deposition onto ice transforms vapour into a solid. Freezing transforms liquid into ice, and melting reverses that path. These words describe different processes involving energy exchanges. Do not replace them all with the word cooling. A temperature decrease may contribute to a process, but saturation conditions and the phases present must be examined.

Microphysics studies transformations and interactions at particle scale. Our guide offers a simplified understanding. It supplies neither a complete cloud simulation nor a local forecasting method. General mechanisms may be known while the exact amount of precipitation remains uncertain. The distinction between explaining a process and forecasting its outcome remains essential.

2. Ascent and cooling

As a parcel of air rises towards lower ambient pressure, it may expand. In an ascent model with no external heat exchange, called adiabatic, this expansion is accompanied by cooling. It is therefore unnecessary to assume that a cold object touches the air to explain every temperature decrease. The model nevertheless depends on conditions: mixing, radiation and water transformations may alter the real situation.

If air cools sufficiently relative to the vapour present, it may reach saturation and then form particles under suitable conditions. Energy released by changes of state modifies the temperature change; saturated ascent does not follow exactly the same model as ascent of unsaturated air. The difference depends on conditions and cannot be reduced to a universal rate valid for every cloud.

Fictional example: for an exercise, we impose a decrease of 8 degrees over one kilometre along a first path and 5 degrees over one kilometre along a second. An initial temperature of 20 degrees would become 12 and 15 degrees respectively after this displacement in the models. These rates are educational parameters, rather than values to use when planning a flight or hike. The result shows only why different assumptions produce different developments.

3. Nuclei and particle formation

Particles present in the atmosphere may facilitate the formation of droplets or ice. Their properties and size matter. Cloud formation must therefore not be represented as an instantaneous transformation of all vapour as soon as a percentage on a screen reaches exactly 100. The process occurs in a medium with varying conditions and particles that behave differently.

A droplet may exist below zero degrees without immediately freezing: this is called supercooled water. This does not mean that the definition of zero degrees is wrong; it shows that a system's state also depends on solid-phase formation and conditions. Clouds containing both liquid water and ice may display particular growth processes. These phenomena require more than a rule based solely on temperature.

Water, aerosols and dynamics interact. Changing a particle count may alter a size distribution without producing an identical consequence in every situation. A general claim that more particles always produce more rain would be excessive. The mechanisms and the domain studied must be examined. This chapter retains that limitation rather than turning a microphysical idea into a weather-modification recipe.

4. Growing into precipitation

Small droplets do not automatically become large drops. Condensation increases their size; collisions may allow coalescence, meaning droplets joining together. Different sizes and relative movements influence encounters. Processes involving ice may also contribute to growth. This diversity of mechanisms explains why one cloud name is insufficient to determine a precipitation total.

An original geometrical demonstration helps us understand scales. The volume of a sphere is proportional to the cube of its radius. Doubling the radius multiplies the volume by eight. To build a particle with a radius ten times greater from identical particles, without losses and conserving volume, one thousand initial volumes would be required. This calculation does not explain the real formation rate; it shows why only a few encounters are not always enough to change scale substantially.

A particle's fall depends on forces, its shape, the medium and air movements. A particle may descend relative to the air while remaining temporarily supported by an updraught. Saying that every drop falls as soon as it has weight would therefore be misleading. Droplets already have mass; what changes is their motion within a medium. Precipitation observed on the ground results from a journey, rather than simply appearing aloft.

5. The journey changes what reaches the ground

A solid particle may melt in a warmer layer; a drop may encounter a cold layer and remain temporarily liquid or change state. Different vertical profiles produce different results at the ground. A temperature measured near a doorway does not describe every layer crossed. Avoid forecasting the precipitation type from a single number without a profile or information about changes over time.

Snow has varied forms and densities. A snow depth and a depth of equivalent water are not interchangeable through a universal fixed ratio. A snowpack may also settle and change after formation. A volume exercise must specify a density or a chosen equivalence. For a real decision in the mountains, this course replaces neither a specialist bulletin nor knowledge of the terrain.

Precipitation may evaporate before reaching the ground. We may see a trail below a cloud without receiving rain at our observation point. Radar may detect particles above an area; interpreting the amount at the ground requires corrections and other information. Do not confuse the absence of drops on your hand with an absence of precipitation throughout the atmospheric column.

6. Classifying clouds without claiming to forecast all the weather

The World Meteorological Organization's International Cloud Atlas distinguishes ten genera: cirrus, cirrocumulus, cirrostratus, altocumulus, altostratus, nimbostratus, stratocumulus, stratus, cumulus and cumulonimbus. This nomenclature makes shared description possible. It does not constitute ten automatic forecasts. Species, varieties and other features supplement the description, but memorising the entire classification is unnecessary to understand the boundary between observation and anticipation.

Filament-like, layered and piled forms provide visual reference points; altitude and vertical development supply other information. A base and top are not necessarily at the same level. Typical ranges vary between regions. A silhouette seen through a window may remain ambiguous; retaining that uncertainty is preferable to inventing a precise identification.

WMO traces the origin of the Latin naming system to Luke Howard's work in 1803. This historical reference shows the value of descriptions that can be shared within an observation-based discipline. It gives the names no magical forecasting property. The Atlas's photographs and tables are not reproduced here; the guide's situations remain educational creations.

7. Two original interpretation scenes

First fictional scene: a group sees piled clouds developing more strongly during the morning. One person immediately announces a time for a thunderstorm. Another records their shape and seeks an updated bulletin. The second approach distinguishes observation from forecasting. Development may be a relevant clue, but this observation alone determines neither time, place nor intensity. An exposed decision requires suitable official information.

Second scene: a station collects no rain while radar shows a signal above the area. Several explanations are possible: precipitation aloft that does not reach the ground, differences in time or location, or limitations of the instrument or representation. Read the metadata before declaring a contradiction. This approach does not claim that every radar image is correct; it organises the checks.

One competing idea claims that knowing a cloud's genus is sufficient to forecast the weather. It recognises a connection between structures and processes, but goes beyond the available information. Another idea says that because identification may be difficult, cloud observations are useless. It overlooks their contribution to describing the environment. A reasonable position recognises limited usefulness and rejects an excessive promise.

8. Progressive exercises with worked answers

Exercise 1 - States and transformations. Distinguish vapour, a droplet and a crystal, then name the change from vapour to liquid and from liquid to solid.

Answer: vapour = invisible gaseous state; droplet = liquid water; crystal = solid state. The vapour-to-liquid change is condensation; liquid-to-solid is freezing. A precise description does not replace these transformations with the word cooling alone. Energy and formation conditions matter, even when temperature helps explain the process.

Exercise 2 - Volume. A fictional spherical particle has three times the radius of another made of the same material. What is the ratio of their volumes? How many small volumes correspond to the large one in a model without losses?

Answer: 3 cubed = 27. Twenty-seven initial volumes are needed to equal the large volume. This geometrical equivalence supplies

neither the number of real collisions nor a growth time. It only conserves volume within the model. A scientific answer must state that scope.

Exercise 3 - Model ascent. With an imposed cooling rate of 7 degrees per kilometre, a fictional parcel of air rises 500 metres from an initial 18 degrees. What result is obtained? Can this calculation alone forecast a real cloud?

Answer: 500 metres = 0.5 kilometre; the decrease is 7 × 0.5 = 3.5 degrees; the model temperature becomes 14.5 degrees. For a real cloud, information is missing, including humidity, changes in the rates, mixing and dynamics. The rate was an exercise assumption. It does not become an atmospheric measurement because the calculation is exact.

Exercise 4 - Fictional water equivalent. An exercise specifies a snow deposit covering 2 square metres to a depth of 0.10 metre, with a density of 100 kilograms per cubic metre. Calculate its volume, mass and the corresponding liquid-water depth, assuming water has a density of 1,000 kilograms per cubic metre.

Answer: volume = 2 × 0.10 = 0.20 cubic metre; mass = 0.20 × 100 = 20 kilograms. Water volume is 20 / 1,000 = 0.020 cubic metre; spread over 2 square metres, it gives 0.010 metre, or 10 millimetres. The ratio comes from the imposed density; it does not automatically apply to every snowfall. No real snowpack assessment is supplied.

Exercise 5 - Signal and observation. A radar signal and a rain gauge appear to contradict one another. Propose four checks before choosing a conclusion.

Possible answer: compare times, areas, observed altitudes and the represented quantity; also check instrument limitations. Radar may observe particles aloft and the rain gauge an amount at the

ground over a duration. Two results may be compatible because they concern different things. If conditions really are comparable, an error remains possible and must be examined.

Exercise 6 - An excessive forecast. Correct “This cloud is a cumulonimbus, so lightning will strike our location in ten minutes” without downplaying a possible danger.

Answer: identification may indicate a situation to take seriously, but provides neither an exact path nor a guaranteed time interval. Consult updated information and apply appropriate protective instructions rather than trying to prove a precise minute. Chapter 7 addresses thunderstorms; no exercise justifies prolonging real exposure.

9. Common mistakes and revision sheet

Common mistakes include seeing vapour, confusing condensation with freezing, associating zero degrees with a universal instantaneous transformation, inferring rain from a cloud name and using a fixed snow-to-water ratio. Another confusion equates a signal aloft with an amount measured at the ground. To correct yourself, follow the particle, its phases, its medium and the observed quantity.

Revision sheet: a cloud contains visible particles; ascent may cool air through expansion; changes of state influence energy; growth is more than initial appearance. Spherical volume varies with the cube of radius. The vertical journey sometimes transforms the type or amount reaching the ground. Classification describes; it guarantees neither a precipitation time nor safety on the ground.

Sources and provenance: WMO, International Cloud Atlas, Genera, https://cloudatlas.wmo.int/en/principles-of-cloud-classification-genera.html ; WMO, Classifying clouds, https://public.wmo.int/world-meteorological-day-2017/classifying-clouds, the Howard 1803 reference; NOAA/NWS, Discussion on Humidity,

https://www.weather.gov/lmk/humidity, distinctions between saturation and precipitation and an introduction to growth. Consulted for the French manuscript on 11 October 2026. Calculations, characters and case interpretations are LFDP originals. No Atlas image or current forecast reproduced.

CHAPTER 6 - FRONTS AND AIR MASSES: DEVELOPMENT, TERRAIN AND LOCAL SITUATIONS

1. From a local measurement to atmospheric organisation

A thermometer indicates temperature at one place; it does not, by itself, describe the air moving above a region. To connect observations, we use concepts including an air mass: an extensive body whose temperature and humidity properties have a degree of consistency. That consistency remains relative. An air mass is not a rigid block, entirely uniform and closed to exchanges; it changes as it moves.

Its source region contributes to its properties, then its journey over sea or land modifies them. Terms such as maritime, continental, polar or tropical describe characteristics and a general history. They do not directly supply the temperature of a neighbourhood at a precise time. Season, terrain, journey duration and exchanges with the surface may change the observed conditions. An air-mass name must not be treated as a complete local bulletin.

This chapter aims to explain how a transition zone and terrain may organise changes. We will use diagrams described in words and fictional numbers. They cannot forecast the real passage of a front today. For an outdoor decision, a dated chart, local forecast and current official messages remain necessary. Understanding mechanisms improves our reading of that information; it does not replace it.

2. A front is a transition, not a wall

A front separates air masses with contrasting properties. A surface chart represents it with a conventional line, whereas the transition has vertical extent and structure. The line is therefore a simplification. It does not mean that all parameters change at exactly the same instant, or that rain is confined to its path.

The words cold and warm are relative to the air masses compared. Air described as cold may feel warm by our usual standards if it replaces even warmer air. The vocabulary mainly indicates how the contrast and movement are organised. This qualification matters when a summer chart appears to show a cold front in a region where temperatures remain high.

A useful but limited metaphor compares a chart to a cross-section of fabric that has been flattened. The line indicates an organisation not fully visible at the surface. Nevertheless, imagining a fixed, impermeable border between two objects would be misleading. Movement, exchanges and mixing are part of the situation. Reading the chart therefore requires linking symbols to observations and to the stated validity time.

3. Cold fronts, warm fronts, stationary fronts and occlusions

A cold front marks the advance of relatively cold air replacing warmer air near the ground. A warm front marks the reverse replacement. Associated vertical movements may favour cloud and precipitation formation, but their intensity depends on humidity, stability and other conditions. A front's name therefore does not impose the same rainfall amount in every situation.

On common conventional charts, triangles indicate a cold front and semicircles a warm front; the side on which they appear indicates the represented movement direction. A stationary front uses alternating symbols on opposite sides. An occlusion uses

alternating triangles and semicircles on the same side. Nevertheless, read the legend supplied by the chart's service: colours alone are insufficient, particularly for black-and-white reproduction or readers who have difficulty distinguishing certain colours.

An occlusion concerns an arrangement in which warm air is lifted and no longer occupies the same near-surface position between colder air masses. It must not be presented as the instantaneous disappearance of all clouds or the guaranteed end of a disturbance. The system may continue developing. Stationary means that the front's position changes little in the representation being considered, rather than that the atmosphere stops moving.

Here we limit ourselves to reading categories. A frontal system's real structure requires observations aloft and tools that this guide does not provide. Seeking an overly simple correspondence between a symbol and experienced weather would obscure the distinction between an explanatory model, chart analysis and forecasting.

4. Why changes do not all follow the surface line

Wind, temperature, pressure and precipitation do not necessarily undergo identical transitions. A cloud may appear before a thermal contrast is measured at the ground; a rain area may extend beyond the front's drawn line. A station is also influenced by its location. Moving from an organised area to a series of local measurements therefore requires interpretation, rather than mechanical reading of a symbol.

An original example uses three fictional stations, A, B and C, forty kilometres apart. An educational chart shows a general west-to-east movement. At A, a temperature decrease is measured at noon; at B, it is measured later; at C, a shower begins before

that decrease. These indications are compatible with an organised development, but insufficient to reconstruct its entire structure. In particular, local effects and measurement precision are unknown.

To reason clearly, separate what is given from what is assumed. Measured times are fictional data in the exercise. Regular movement is a simplifying assumption. Claiming that the same sequence will reach a fourth station would be a forecast requiring additional information. This classification prevents a school illustration from becoming a movement rule applied to a real event.

A causal question can also be asked: does the shower cause the temperature change, or do several processes contribute to both observations? Chronological succession alone cannot decide. Precipitation and its effects may change local temperature; the arrival of a different air mass may also matter. A good explanation retains several compatible mechanisms rather than choosing the first connection that comes to mind.

5. Terrain organises local differences

When a flow encounters terrain, air may be directed towards a higher altitude. Its expansion and cooling may favour saturation if its humidity permits. This helps explain some differences between slopes. It does not mean that rain falls on every mountain whenever wind blows, or that a sheltered slope always stays dry.

Terrain also alters the flow: a pass, valley or slope does not necessarily experience the same wind as the nearest lowland station. Some differences are smaller than a forecast model's grid cells. In its work on orography, the Met Office emphasises the need to represent mountain effects in models. Our purpose is not to supply a universal personal correction, but to understand why a regional forecast may have local limitations.

An original example compares two fictional places on opposite sides of a mountain range. The windward station reports persistent clouds and rain; the leeward station reports brighter intervals. The terrain makes a difference plausible, but does not automatically attribute the entire difference to uplift alone. Altitude, time, instrument and the general situation must also be examined. A satisfactory explanation connects clues; it does not turn one factor into an exclusive cause.

It is tempting to create a rule such as adding a fixed number of kilometres per hour to wind whenever one climbs. Terrain alone does not justify such a rule. Effects depend on orientation, stability and flow structure. For hiking, activities at height or an exposed installation, consult information appropriate to the place and activity, rather than only the value for a neighbouring town.

6. An educational cross-section and a limited calculation

Imagine a fictional transition line one hundred and twenty kilometres from a point, moving directly towards it at thirty kilometres per hour, within the exercise only. If speed and direction remain constant, the geometrical duration is distance divided by speed, or four hours. Units cancel appropriately: kilometres divided by kilometres per hour gives hours. The calculation is consistent with its assumptions.

This result is not a real arrival time for rain. The represented position may be uncertain, speed may change, and precipitation may be displaced relative to the line. The component of velocity towards the point also matters: oblique movement cannot be treated like movement directly towards the place. The four hours express only what the simplified scenario's numbers produce.

Add a fictional speed range of twenty to forty kilometres per hour, retaining a fixed distance and direction. The durations become six

hours and three hours. This gives a range of geometrical scenarios, rather than a probabilistic interval validated by observations. Nothing establishes a particular probability that the real duration lies between those values. A range of calculations and a probabilistic forecast are different things.

This distinction will return in the chapters on models and probabilities. It already provides a useful reading rule: an exact operation may rest on assumptions too simplified to guide a decision. Arithmetic precision does not remove uncertainty in the data or model.

7. A verified historical reference

The Met Office's historical factsheet connects the modern representation of fronts with the Bergen school and describes a proposal for monochrome symbols by Tor Bergeron in 1924. We retain this limited reference: triangles and semicircles communicate a distinction without relying on colour alone. It does not claim that every contemporary tool already existed in its current form.

This history illustrates a problem shared by the sciences: representation should make understanding, comparison and communication possible. A symbol may remain useful while greatly simplifying its object. Learning consists of knowing both its purpose and limitation. It must neither be mistaken for the atmosphere itself nor rejected because it does not show every property.

8. Progressive exercises with worked answers

Exercise 1. A chart shows a cold front even though the temperature after its fictional passage is twenty-eight degrees. Is this a contradiction?

Answer. Not necessarily. Cold describes a contrast between air masses here, rather than a universal temperature that an observer considers cold. The replaced air's temperature and the context are missing. The mistake would be turning a relative description into an absolute threshold. This answer permits no conclusion about current weather in a region.

Exercise 2. A fictional frontal line is ninety kilometres away and advances directly towards a place at fifteen kilometres per hour. Calculate the simplified duration, then give three reasons not to announce the exact time of rain.

Answer. The duration is ninety divided by fifteen, or six hours. Movement may change, the initial position may be uncertain, and rain may lie ahead of or behind the line. Direction and local effects could also be added. The calculation answers a conditional geometrical question; it is not an operational bulletin.

Exercise 3. Two nearby towns have different observations. Propose an approach that does not immediately conclude that a measurement error has occurred.

Answer. First check times, locations and instruments. Then examine altitude, exposure and proximity to terrain or a coastline. Compare these data with dated regional information. A difference may be real, instrumental or linked to comparison conditions. The approach organises hypotheses before choosing an explanation.

Exercise 4. A classmate claims that an occlusion means immediate fine weather and that a stationary front means no wind. Correct both claims.

Answer. An occlusion describes the arrangement of air masses and uplift; it does not guarantee that clouds or precipitation disappear. Stationary concerns the front's position, rather than the stopping of

every flow. Both sentences attribute a consequence to a mapping category that its definition does not contain.

9. Common mistakes and revision sheet

Do not confuse a chart line with a rigid vertical border. Do not read cold and warm as fixed thresholds. Do not equate a movement speed with the time of rain. Do not transfer a lowland value to a slope without suitable information. Finally, a chart without a date or legend may become an educational document, but must not serve as evidence of the current situation.

For revision, define air mass, cold front, warm front, stationary front and occlusion. Explain why moving over a surface changes properties. Describe terrain's possible role without promising an outcome. Repeat the distance-divided-by-speed calculation while stating every assumption. Finish by distinguishing measurement, interpretation and forecasting: these three operations are connected, but their results do not have the same scope.

10. Primary sources and further reading

NOAA, How to read Surface Weather Maps, definitions and conventions: https://www.noaa.gov/jetstream/wxmaps Met Office, Weather fronts: https://weather.metoffice.gov.uk/learn-about/weather/atmosphere/weather-fronts Met Office, Rain, frontal and orographic uplift: https://weather.metoffice.gov.uk/learn-about/weather/types-of-weather/rain Met Office, Orographic processes, challenges in representing terrain: https://www.metoffice.gov.uk/research/foundation/parametrizations/orography Met Office, Factsheet 10, Air masses and weather fronts, particularly the historical section “A brief history”: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/library-and-archive/library/publications/factsheets/factsheet_10-air-masses-and-weather-fronts_2023.pdf Sources checked for the French manuscript on 11 October 2026. No publisher's diagram or table is reproduced; examples, calculations and exercises are original and fictional. This chapter provides no current weather information.

CHAPTER 7 - THUNDERSTORMS, LIGHTNING AND SEVERE PHENOMENA: MECHANISMS AND FORECAST LIMITS

1. Organised formation, distinct hazards

A thunderstorm combines electrical activity with a developed convective cloud. Lightning, heavy precipitation, hail and gusts may constitute different hazards within the same situation. We must not wait for all of them to appear before recognising a risk. The absence of rain where we stand does not prove the absence of danger from a nearby thunderstorm.

Convection is movement that transports, among other things, energy and matter. In a favourable atmosphere, air may rise, cool, form clouds and participate in a deeper organisation. Humidity, stability and a triggering mechanism matter. However, the presence of some favourable ingredients does not automatically establish that a thunderstorm will form at a particular place and precise minute.

This chapter helps readers understand words used in a bulletin and recognise the limits of personal interpretation. It does not train readers to chase storms, supply a current warning or replace official instructions. Examples are fictional. Every educational observation is made from a safe situation; no exercise asks anyone to approach a thunderstorm or stay outdoors to take a measurement.

2. Updraughts and downdraughts

A convective cell contains air movements. Development is fed by an updraught; precipitation and cooling processes may contribute to downward movements. In its explanation of the mature stage, NOAA states “updrafts and downdrafts coexist”, meaning that upward and downward currents coexist. This short reference emphasises that a developed thunderstorm is more than a column of rising air.

Cooling and precipitation may favour a downward flow that spreads near the ground. This behaviour helps explain gusts sometimes distant from the most visible rain area. A photograph does not capture every movement. The spectacular part of a cloud and the area most relevant to a decision are therefore not necessarily the same.

The distinction between a cell diagram and a real system must be retained. Several cells may form, merge or renew; a lasting organisation may continue while one particular cell weakens. An educational cell duration is not a safety timer. We cannot announce that a hazard will end after a fixed number of minutes because a course presents a sequence of stages.

An explanatory model is useful when it shows relationships between supply, development and change. It becomes misleading if an exact timetable is inferred without updated observation. This difference returns in the chapters on numerical forecasting and decisions.

3. Lightning flashes, strikes and thunder

Movements and interactions between particles in a cloud contribute to the separation of electrical charges. A discharge may occur within a cloud, between clouds, or between the atmosphere and the ground. Its visible light is the lightning flash; thunder is the sound associated with very rapid heating and expansion of the air. Seeing a flash before hearing thunder is explained mainly by the different propagation speeds of light and sound.

Scientific description does not enable us to identify the next strike location with certainty. A person may see distant activity without having complete information about every discharge. Spectacular temperature or voltage figures sometimes quoted do not provide a method of personal protection. Understanding a phenomenon and controlling its occurrence are distinct abilities.

A distance calculation from a delay can illustrate sound propagation, but does not define a safe outdoor area. The National Weather Service notes that hearing thunder indicates a situation in which lightning may pose a danger. This guide therefore proposes no personal threshold for waiting outside. Official shelter instructions take priority over the desire to finish an observation.

4. Hail, intense rain and gusts cannot be inferred from one image

Hail develops notably through ice accumulating around particles within a thunderstorm's currents. Droplets may remain liquid below zero degrees before freezing on contact. Growth, suspension and falling depend on conditions that cannot be read from a simple sky colour. A layer of ice observed on the ground is insufficient to reconstruct a hailstone's entire journey.

Heavy rain can rapidly concentrate water on an area. Its effects depend on duration, soil, slope, drainage and upstream flows. An

average amount across a region does not necessarily describe the accumulation in one neighbourhood. Similarly, a gust is a brief change in wind; it differs from an average indicated over a period.

In an original example, two fictional places receive the same rain accumulation over one hour. The first has functioning drainage; the second lies at the foot of a slope and also receives runoff. Consequences may differ even though the local rain figure is identical. This case shows why risk depends not only on an atmospheric measurement, but also on exposure and surroundings.

Inferring from this case an ability to cross a flooded area by estimating its depth would be dangerous. The exercise explains different effects; it validates no crossing. A road, bridge or ground surface may have damage that cannot be seen. Closures and authorities' instructions take priority over personal analysis from a distance.

5. Tornadoes and other phenomena: do not simplify complex causation

A tornado is a strongly rotating column of air connecting a convective cloud with the ground. Not every thunderstorm cell produces one. Mechanisms depend on a complex organisation of movements, notably changes in wind with altitude and processes specific to the cell. The National Weather Service emphasises that air masses meeting, presented alone, is an overly simplified explanation of formation.

This finding does not mean that all knowledge is useless. Favourable conditions can be identified and monitoring systems may provide warnings. Nevertheless, forecasting a favourable environment and predicting a very local phenomenon with an exact location and intensity are different abilities. Uncertainty at

fine scales does not remove the need to follow a protective message.

A common mistake is debating a phenomenon's precise name at length before following an instruction. For an exposed person, the announced danger, requested action and affected place take priority. Scientific classification can be studied afterwards. This guide supplies no field-identification exercise and requests no close-up photograph.

6. An educational propagation calculation

In a fictional scenario studied from a recording, six seconds separate the light and sound. Take a simplified sound speed of three hundred and forty metres per second and neglect light's travel time at this scale. The product is two thousand and forty metres, or approximately two kilometres. Rounding matches the assumptions: announcing two kilometres and forty metres as an exact measurement would be excessive.

Add an educational uncertainty of one second to the delay. With five seconds, the calculation gives one thousand seven hundred metres; with seven seconds, two thousand three hundred and eighty metres. This variation shows how timing uncertainty affects the result. We can also examine the effect of a different assumed speed, because propagation depends on the medium's conditions. The purpose is to connect measurement, assumption and result, rather than assess a protective distance.

Why is the calculation insufficient to decide whether to stay outside? It concerns an event that has already occurred, rather than the next one. It simplifies the sound's path and atmospheric conditions. It describes neither the system's entire extent nor every possible strike location. Finally, waiting to calculate may

delay sheltering. An operation's educational value and relevance to safety must be assessed separately.

Classwork may use an authorised audio file and video, or an entirely written scenario. It must never require learners to obtain the sequence themselves during a dangerous situation. Scientific curiosity can be exercised without creating the exposure it seeks to understand.

7. Two bulletin-reading scenarios

First original scenario: a fictional outing is to take place near a suitable building, while a current bulletin within the exercise announces a thunderstorm risk in the area. The group knows a shelter location but not how long it would take to move every participant there. The priority question is not visually forecasting the exact time. Applicable instructions, the time needed to act and the possibility of postponing the activity must be checked.

Second scenario: a fictional organiser notices a bright interval and wants to consider the system finished. Yet the exercise's dated information still indicates activity in the area. A local bright interval is an observation, rather than sufficient confirmation that danger has ended. A decision must incorporate current monitoring and the site's rules. The guide supplies no universal resumption time; official recommendations and the responsible people must determine what to do.

These situations show an important asymmetry. Starting to protect oneself does not require perfect knowledge of every mechanism. Announcing that danger has disappeared requires more than a simple impression. Recognising this asymmetry prevents scientific uncertainty from becoming an excuse for inaction or premature resumption.

8. Progressive exercises with worked answers

Exercise 1. Distinguish a lightning flash, thunder and a cloud-to-ground lightning strike in a short paragraph. Explain why perceiving them cannot calculate the next strike location.

Answer. A flash is the luminous manifestation of a discharge; thunder is its sound effect; a cloud-to-ground strike is a discharge between the atmosphere and the ground. A perceived event provides information about what happened, subject to observational limitations. It does not give the exact conditions of every future discharge. Protective instructions must therefore be followed rather than converting this perception into a guarantee.

Exercise 2. In a fictional recording, the delay is nine seconds. Use the simplified speed of three hundred and forty metres per second, then explain the appropriate precision.

Answer. The product is three thousand and sixty metres. Approximately three kilometres is appropriate given the assumptions and limited timing. Multiplication is exact for the chosen numbers, but the physical distance does not necessarily have that exactness. This result defines no safe outdoor distance.

Exercise 3. A visible cell weakens and a student concludes that the whole thunderstorm system has ended. What information is missing?

Answer. The state of other cells, the possibility of renewal and updated information about the area are missing. A system may contain several organisations that develop differently. Observing one cell is insufficient to reach a conclusion about the whole. The answer does not predict that renewal will occur; it shows that the conclusion has not been established.

Exercise 4. A fictional bulletin announces possible strong gusts without giving the exact point that will experience them. Is it unusable? Propose an argument.

Answer. An absence of exact localisation does not remove all information. Possible gusts in an area may make an activity or installation vulnerable and justify a measure specified by suitable instructions. The decision depends on exposure, alternatives and the competent authority. Uncertainty cannot be used to prove that the chosen place will be spared.

9. Common mistakes and revision sheet

Do not turn a cell diagram into a guaranteed duration. Do not confuse no rain with no lightning. Do not present a distance calculated after a flash as a protective threshold. Do not reduce a tornado to air masses meeting. Finally, a spectacular photograph or an impression of calm replaces neither dated information nor current instructions.

For revision, connect updraughts, downdraughts, precipitation and gusts without assuming an identical sequence every time. Distinguish the hazards within one system. Explain why an exact calculation may be unsuitable for a safety decision. Finally, propose an educational observation without exposure: working with an authorised recording is often more useful than trying to produce a dangerous measurement yourself.

10. Primary sources and further reading

NOAA, Life Cycle of a Thunderstorm, short reference on movements: https://www.noaa.gov/jetstream/thunderstorms/life-cycle-of-thunderstorm National Weather Service, Understanding Lightning Science: https://www.weather.gov/safety/lightning-science-overview NOAA, Thunderstorm Hazards - Hail: https://www.noaa.gov/jetstream/hail NOAA, Types of Thunderstorms: https://www.noaa.gov/jetstream/tstrmtypes National Weather Service, Tornadoes FAQ, explanatory and forecasting limitations: https://www.weather.gov/lmk/tornadoesfaq National Weather Service, Lightning Safety: https://www.weather.gov/safety/lightning-safety Sources checked for the French manuscript on 11 October 2026. The English quotation contains four words; no illustration, casualty statistic or performance table is reproduced. Calculations and scenarios are original. No current warning or medical procedure is supplied.

CHAPTER 8 - Numerical forecasting: initial conditions, models and ensembles of scenarios

1. Forecasting means calculating development from an estimated state

A weather forecast describes possible future states of the atmosphere. It is neither a mechanical continuation of yesterday's observed weather nor merely recognition of a cloud shape. It combines observations, physical laws, numerical methods and expertise. The result has a lead time, area, variables and limitations. A near-surface temperature forecast for tomorrow does not directly answer a question about gusts on a ridge in three hours.

An initial condition is the state from which a calculation begins. For the atmosphere, this includes temperature, humidity, pressure and air movement at many points and levels. Ideally, these quantities would be known everywhere at the same instant. Observations nevertheless remain scattered, uncertain and sometimes absent. A satellite, station and balloon do not measure exactly the same things at the same places and times.

Data assimilation constructs a coherent estimate of this state. It compares checked observations with a prior estimate, often supplied by a recent forecast. A new measurement therefore does not automatically replace the entire calculated field. Its precision, representativeness and consistency matter. If a thermometer measures near a heated wall, its number may be correct for that point without representing an entire model grid cell.

In ECMWF's institutional description, this analysis supplies the starting point for subsequent forecasts; observations and models both have uncertainties. Remember the general logic: observe, check, compare, adjust, then calculate development. This educational summary does not describe every operational method. Assimilation is neither a simple average of all available numbers nor a way to know the present perfectly.

2. A discrete representation of a continuous medium

A numerical model is a computable representation of certain processes. An atmospheric model organises equations, data and approximations. A grid cell represents a portion of space. A time step is the interval between two calculation stages. Real air does not move through boxes and jumps: this organisation serves calculation, rather than defining reality.

Resolution indicates the fineness of this representation. A finer grid may distinguish terrain or certain movements better, but does not make every phenomenon directly computable. A small eddy, droplet or street often remains smaller than a cell. Some effects must therefore be represented through simplified relationships called parametrisations. A parametrisation is not an arbitrary number: it expresses an unresolved effect at the scale used, with assumptions to evaluate.

Imagine a square region divided into ten cells along each horizontal direction: it contains one hundred cells. Doubling that number along both directions gives four hundred cells, four times as many. If the vertical resolution also doubles, the number of volumes becomes eight times greater. This geometrical experiment does not predict the exact calculation time: time steps, communication between machines and the numerical method introduce other costs.

Fine resolution does not ensure a good forecast if the initial state is wrong, processes are poorly represented or the result is misinterpreted. A highly detailed drawing may give a misleading impression of certainty. Spatial detail, accuracy and reliability must be distinguished: these qualities are connected, but none automatically replaces the others.

3. Understanding a numerical step through a controlled example

Consider a fictional cooling model. An object has temperature T while its surroundings remain at 10 °C. We assume its cooling rate is proportional to the difference T − 10, with a coefficient k = 0.25 per hour. This model represents neither a cloud nor a city's future temperature. It only helps explain the transition from a continuous relationship to a calculation in steps.

For a step h expressed in hours, use the rule next T = current T − k × h × (current T − 10). The product k × h is dimensionless. The thermal difference is a difference between temperatures: its numerical value is the same in degrees Celsius and kelvins. Starting from 18 °C with h = 1 hour, the first result is 18 − 0.25 × 8 = 16 °C. After a second step, it is 16 − 0.25 × 6 = 14.5 °C.

Repeat the calculation with h = 0.5 hour. The successive values are 17, 16.125, 15.359375 and then 14.689453125 °C after two hours. Both methods apply the same starting relationship but approximate its development differently. Their final difference is about 0.189 °C. This difference illustrates a discretisation effect; it is not a measured meteorological uncertainty.

With the continuous solution of this elementary model, T after two hours is 10 + 8 × exp(−0.5), approximately 14.852 °C. If the exponential function has not yet been studied, comparing the two calculations is sufficient to grasp the idea. Reducing the step

improves the approximation here. This finding must not be generalised without examination to every method, phenomenon and setting.

A useful check also examines qualitative behaviour. In this case, temperature should approach 10 °C rather than move away without a cause. An excessively large step might produce an inconsistent development. Checking a model therefore combines calculation, units and physical meaning. Displaying many decimal places proves none of these qualities.

4. Initial uncertainty, model uncertainty and sensitivity

An initial error is a difference between the state used and the real state. It may originate in a measurement, an unobserved area or an imperfect estimate. Model error results from the chosen equations, approximations, parameters or calculation. Interpretation error occurs when a user gives the result a meaning that it does not possess. These three must not be confused.

Some atmospheric developments amplify small initial differences. In a chaotic system, imperfect knowledge of the starting state progressively limits possible precision. Chaotic does not mean lawless or entirely random. A trajectory may be determined by rules while remaining difficult to forecast far ahead because its starting point is not known with infinite precision.

Our cooling object does not illustrate this amplification: two nearby initial temperatures tend to converge here as they cool towards the same surroundings. This limitation is part of the demonstration. A simple example helps explain discretisation, but must not claim to represent every atmospheric behaviour. An educational model is useful when we name what it explains and what it leaves aside.

Now suppose that a rain area is forecast near a boundary between two districts. A slight shift in its path may greatly change rain

received at one point, even if the regional description remains fairly similar. The difficulty concerns not only amount but also position and timing. A spatial average may conceal this local sensitivity.

5. Why produce several scenarios?

An ensemble forecast explores several developments, obtained particularly by varying the initial state and certain model representations. A member is one calculated scenario within that ensemble. The ensemble helps examine spread and possible events. Members are not necessarily independent; they may share data, structure and errors. Agreement between them is therefore not absolute proof.

In a fictional example, five scenarios give 15, 16, 16, 17 and 20 °C. Their mean is 16.8 °C and median 16 °C. The mean summarises the series, but no scenario gives exactly 16.8 °C. A rainfall mean may likewise conceal a contrast between dry and rainy scenarios. Examine the distribution, rather than only its centre.

Only the members at 17 and 20 °C reach at least 17 °C in this example, two out of five. This proportion describes our small series. It does not by itself establish a real meteorological probability of 40%. Such an interpretation requires knowing how the ensemble is constructed, its calibration and the event definition.

Calibration checks whether announced probabilities correspond to observed frequencies over relevant series. A method may provide a tightly clustered distribution while being overconfident. It may also produce excessive spread. Reliability and sharpness must be evaluated together; a less spectacular forecast may better represent what is actually known.

The next chapter examines these probabilities more closely. For now, remember that an ensemble is not a vote by omniscient machines. It organises scenarios to characterise uncertainty better. It replaces neither updated observations nor interpretation by the responsible services.

6. From calculation to bulletin: dates, places and expertise

Initialisation time identifies the start of the calculation. Validity time identifies the moment to which a result refers. Lead time is the difference between them. A chart from a calculation initialised on Monday at midnight may show a situation on Tuesday at noon. The date when the image was downloaded does not turn an old calculation into a new forecast.

Times also require explicit attention. UTC and local time are not interchangeable; the offset depends on location and sometimes season. Read the document's convention rather than guessing. A forecast without a complete date, area or units is difficult to use even if its graphics look familiar.

A grid-cell result is not necessarily the exact value outside a house. Terrain, exposure, altitude and the immediate surroundings may alter the situation. Producing a bulletin accounts for these differences and the context. Human expertise examines new observations, several outputs and known limitations. It is more than copying a colour from a chart.

To retain a forecast in a notebook, record the provider, initialisation if specified, validity, area, variable and uncertainty. When an update appears, compare these elements before comparing numbers. A change may reflect additional observations; it does not, by itself, prove that all previous calculations were useless. An absence of change is equally not a guarantee.

7. Historical references and changes in method

Numerical forecasting developed alongside physical methods, observations and computing resources. The Met Office dates its first operational computer forecast to 2 November 1965, following earlier experimental work. This reference concerns that organisation, rather than claiming a world first. It shows the gradual transition from an experiment to a regular service.

ECMWF states that it produced its first operational forecasts in 1979 and its first ensemble forecasts in 1992. These dates, checked in its institutional presentation, illuminate uncertainty's growing role. Configurations, member counts and technical resources change: figures from a historical factsheet must not automatically be attributed to the current service.

Nevertheless, telling this history as the complete replacement of people by computers would be misleading. Observations must be designed and checked, models studied and results evaluated. Calculation expands possibilities; it does not remove the obligation to define what is measured and acknowledge what is unknown.

8. Progressive exercises and worked answers

Exercise A - A measurement of 25 °C comes from a sensor exposed near a building facade. Can it be used as a temperature representative of an entire region? Answer: not without examining its location and representativeness. Distinguish the measurement's quality at its own point from its relevance to the model's scale. A real number may be misused; automatically rejecting every local observation would nevertheless be another error.

Exercise B - In our fictional model, start at 22 °C, use k = 0.25 per hour and two one-hour steps. Answer: the initial difference from the surroundings is 12; T1 = 22 − 3 = 19 °C. The second difference

is 9; T2 = 19 − 2.25 = 16.75 °C. The result develops towards 10 °C. This calculation says nothing about tomorrow's temperature.

Exercise C - Ten scenarios give 0, 0, 0, 0, 0, 0, 4, 4, 8 and 14 mm over a fictional period. Calculate mean, median and the strictly positive proportion. Answer: the sum is 30 mm and the mean 3 mm; the fifth and sixth values are zero, so the median is 0 mm. Four values are positive, 40% of the series. Saying that all scenarios announce light rain of 3 mm would be false.

Exercise D - A calculation initialised at 00:00 UTC supplies a field valid at 18:00 UTC on the same day. What is its lead time? Answer: eighteen hours. Without a date and local convention, this field cannot be converted to an exact local time. Specify the missing information before continuing.

Exercise E - An advertisement claims: “Our chart has more pixels, so it is more reliable.” Construct an objection. Answer: displayed pixels prove neither calculation resolution nor accuracy. Even a finer grid may share initial or physical errors. Results must be evaluated against observations for a defined variable, area and lead time.

Exercise F - Write a paragraph distinguishing a model from reality. Suggested answer: a model simplifies certain processes to produce a checkable calculation. Its results must be compared with observations. A simplification is acceptable if its domain of use and effects are studied; it becomes misleading if given a certainty or scale that it does not possess.

9. Common mistakes and revision sheet

Do not confuse a measurement with a global analysis, an analysis with a future forecast, a member with a certain probability, or a mean with one unique scenario. Do not use spread alone as a guarantee of reliability. A date error may be more serious than a difference in decimal places. Lack of a network connection does not allow a saved forecast's validity to be extended indefinitely.

Revision sheet: observations and a prior estimate construct the analysis; a model evolves this state using approximations; grid cells and time steps organise the calculation; several scenarios explore uncertainty; expertise interprets outputs at a useful scale. Always identify initialisation, validity, place, units and provider. Our cooling calculation is an educational demonstration, never an operational bulletin.

10. Checked primary references

ECMWF, “Data assimilation”: https://www.ecmwf.int/en/research/data-assimilation ; “Fact sheet: Ensemble weather forecasting”, 2017: https://www.ecmwf.int/en/about/media-centre/focus/2017/fact-sheet-ensemble-weather-forecasting . Consulted for the French manuscript on 11 October 2026; general methods and historical references, without presenting a historical numerical configuration as current.

Met Office, “History of numerical weather prediction”: https://weather.metoffice.gov.uk/learn-about/how-forecasts-are-made/history-of-numerical-weather-prediction ; “How forecasts are made”: https://weather.metoffice.gov.uk/learn-about/how-forecasts-are-made . Consulted for the French manuscript on 11 October 2026. The chapter's examples, calculations and exercises are original and fictional; no verbatim quotation from these pages is used.

CHAPTER 9 - Probabilities and uncertainty: reading a bulletin without false precision

1. A percentage must refer to a defined event

A probability quantifies a possibility within a given framework. It lies between zero and one, or between 0 and 100%. Without an event definition, the percentage remains incomplete. “60%” may concern measurable rain at a place, a temperature exceeding a threshold, or a climate category over a season. These events have neither the same duration nor the same threshold.

Define a fictional event: receiving at least 2 mm of rain at a point named A between 14:00 and 20:00 on a specified date. This definition contains a variable, threshold, place and period. It does not say whether the rain falls in ten minutes or six hours, or whether a neighbouring point B receives the same amount. Changing any one of these elements changes the question and may change the probability.

A National Weather Service factsheet explains its precipitation probability through a measurable amount, a point and a specified period. It clarifies that a percentage does not automatically mean the fraction of time with rain or the fraction of area covered at an instant. Its particular threshold belongs to this American product; it must not be imposed on every provider. To read a real service, seek its own definition.

“There is a 30% probability of this event” therefore means neither “it will rain for 30% of my outing” nor “the rain will be light”. A relatively low probability may concern an intense event. A high probability may concern a small amount. Probability, intensity and

duration are three distinct pieces of information, even when they appear on the same line.

2. Observed frequency and announced probability

Frequency is a proportion calculated within a series of observations. If an event occurs 12 times out of 40, its frequency is 12/40 = 0.30. A probability announced before an event is an estimate. The two can be compared across relevant series; a small sample's frequency does not automatically become a general law.

A method that often announces 30% may be called well calibrated for that class of situations if the event occurs approximately three times in ten over a sufficiently large, appropriately defined sample. This does not mean that every successive group of ten contains exactly three events. Fluctuations occur, and cases may be related.

In a fictional series of 200 comparable forecasts at 30%, 64 events are observed, or 32%. This difference alone does not establish that the method is perfect or faulty. Sample size, dependencies, event definitions and method stability must be examined. By contrast, 150 events over those same 200 cases would clearly call for investigation: the departure from 30% would be large.

The Met Office presents this evaluation through probability groups and explains calibration's usefulness. It states: “ensembles cannot provide a perfect representation of probability”. These eight words invite us to evaluate methods instead of treating their numbers as perfect. A particular forecast is realised or not; a probability's quality is assessed through many cases rather than one spectacular success. An 80% forecast followed by no event is not logically impossible. It is still necessary to check whether such non-occurrence is exceptionally expected or too frequent.

3. Precise results are not necessarily reliable

Precision may refer to numerical detail, for example 17.284 °C. Accuracy concerns closeness to a relevant reference value. Probabilistic reliability concerns statistical agreement between announced probabilities and observed events. A result may look very precise without being accurate or reliable. These words must be separated before comparing products.

Consider two fictional services forecasting a future temperature. The first displays one value, 18.00 °C, without explaining its margin. The second indicates a probable range of 16 to 20 °C, with its definition and limitations. The second display looks less assured but may better represent uncertainty. A wide range is not automatically useful, however: it must be informative and evaluated.

An interval forecast at 80% means, within a correctly calibrated framework, that approximately 80% of comparable cases should fall within it. That framework and method must be known. This does not turn the interval's limits into physical barriers. An outside value remains possible. Confidence in a forecast must not be confused with a contractual guarantee or a safety commitment.

When comparing two charts, examine their variable, scale, lead time and definition before considering which displays more decimal places. Values from different points, altitudes or durations do not become comparable through a colour change. Visual precision may conceal a difference in the question.

4. Several hours: why not add the percentages?

Suppose two successive periods each have a rain probability of 40%. Adding 40 and 40 to conclude 80% over the whole is generally wrong. Events may overlap: the same disturbance may affect both periods. Their relationship matters as much as their separate probabilities.

If A denotes rain in the first period and B rain in the second, the probability of A or B equals P(A) + P(B) − P(A and B). The overlap counted twice must be removed. With P(A) = P(B) = 0.40 and P(A and B) = 0.25, the probability of at least one rainy period is 0.55, or 55%. This is a fictional calculation, rather than a hidden interpretation of an app.

If the events were independent, the overlap would be 0.40 × 0.40 = 0.16, giving 64%. Independence, however, is an assumption rather than a reflex. Neighbouring weather periods are often related. Without information about that relationship, the two percentages do not yield one unique result for the whole.

The same caution applies to several places. Rain in two neighbouring towns may arise from the same system. Multiplying or adding their probabilities without a joint model invents information. From a purely mathematical perspective, for two events at 40%, the probability of at least one lies between 40 and 80%. These bounds do not locate the correct meteorological estimate.

5. Conditional probability: context matters

A conditional probability concerns an event when another is known to have occurred. P(A given B) does not mean P(B given A). For example, the proportion of rainy days among cloudy days is not necessarily the proportion of cloudy days among rainy days. The starting group changes.

In a fictional notebook of one hundred days, sixty are classified as cloudy and twenty as rainy. Fifteen belong to both categories. Rain frequency among cloudy days is 15/60 = 25%. Cloudy-day frequency among rainy days is 15/20 = 75%. Both results are correct, but answer different questions. This notebook's categories and sample constitute no real model.

A new observation may alter an estimate. However, observing a dark sky locally is insufficient to recalculate the probability of a severe phenomenon oneself. Relevant data and a validated method would be needed. Conditioning teaches us to ask the right questions; it does not supply an improvised warning tool.

Climate references also have a context. An anomaly is a departure from a defined reference, often an average over a period. “Warmer than normal” requires knowing that normal. A seasonal probability of an anomaly does not precisely forecast a particular day's temperature. Timescale and statistical definition must remain visible.

6. From risk to decision: consequences and alternatives

A phenomenon's probability is not its consequence. A hazard is the potentially damaging phenomenon; exposure identifies what lies within its area; vulnerability concerns sensitivity and the means available to cope. The next chapter develops these distinctions. The same rainfall may have different consequences for ground, a building or an activity.

Decision reasoning can compare costs in a situation without safety implications. Imagine an exhibition of drawings that can be moved indoors for 12 fictional cost units. If a shower occurs outdoors, material damage costs 80 units. With an assumed probability of 20%, the theoretical average loss from staying outside is 0.20 × 80 = 16 units, exceeding the relocation cost.

This calculation assumes comparable costs, a relevant estimate and that moving really prevents the damage considered. It does not guarantee that a shower will occur; it compares choices before the outcome is known. If no rain occurs, relocation may still have been a reasonable decision when made.

The same model must not be applied as permission to risk a life. Obligations, regulatory thresholds, irreparable harm and the severity of consequences alter the reasoning. Official instructions and activity managers' instructions take priority. The school calculation helps explain uncertainty; it does not replace professional safety analysis.

A good decision also has alternatives: postponing, reducing exposure, choosing another place or cancelling. Waiting for absolute certainty may be impossible; acting as though every possibility were certain may also make all activity impractical. The issue is to use appropriate, updated information according to consequences and applicable rules.

7. Evaluating without selecting only successes

A verification notebook must record the forecast before the outcome, then the same observed variable at the defined place and period. Changing the threshold or area afterwards creates an artificial advantage. Selecting only memorable episodes also distorts evaluation. Ordinary situations and errors must be retained too.

A method that always announces “no heavy rain” may often look correct in a climate where that event is rare, yet provide no useful information when it occurs. An overall success rate is therefore insufficient. We must examine what the method detects, what it misses and how it compares with a simple reference.

For an exercise, an elementary score can be created: for each binary event, assign y = 1 if it occurs and y = 0 otherwise; calculate $(p - y)^2$, then take the mean. A probability p = 0.8 followed by an event gives 0.04; the same forecast followed by non-occurrence gives 0.64. The calculation penalises strong confidence contradicted by the outcome. This small mathematical example is insufficient to validate a real service or diagnose every error.

Evaluation must remain connected with the domain studied. Short-lead regional temperature results do not demonstrate identical qualities for a local thunderstorm or a future season. A relevant comparison uses the same cases, definitions and observations. When these elements are missing, the honest conclusion concerns insufficient evidence, rather than invented superiority.

8. Progressive exercises with worked answers

Exercise A - A bulletin indicates a 70% chance of precipitation over a period. Can intensity be inferred? Answer: no. The threshold definition and information about amount, duration or intensity are needed. The percentage concerns the provider's defined event, rather than automatically describing heavy or light rain.

Exercise B - In 120 cases forecast with a probability of 25%, the event occurs 36 times. What is the frequency and what can be concluded? Answer: 36/120 = 30%. The difference from the forecast is five percentage points. Judging calibration requires more information: sampling uncertainty, comparability and case dependencies. Do not say “five per cent error” without specifying the meaning.

Exercise C - Two periods each have a 50% probability of an event and their overlap is 35%. Calculate the probability of at least one

occurrence. Answer: 50 + 50 − 35 = 65%. Assuming independence would give 75%, but that assumption would be incompatible with the given overlap.

Exercise D - In a fictional series, 40 days are windy, 10 have material damage, and 8 have both characteristics. Compare the two conditional frequencies. Answer: damage among windy days, 8/40 = 20%; wind among days with damage, 8/10 = 80%. This does not prove that wind is the sole cause of all damage.

Exercise E - Revisit the drawing exhibition with a probability of 10%. Answer: the fictional average loss from staying outside becomes 8 units, against 12 for moving. This comparison favours staying outside within this very limited model. It accounts for neither other costs nor obligations; it supplies no universal threshold for an exposed activity.

Exercise F - Three forecasts p = 0.2, 0.7, 0.9 are followed by y = 0, 1, 1. Calculate the mean elementary score. Answer: squares 0.04, 0.09, 0.01; sum 0.14; mean approximately 0.0467. These three cases are insufficient to rank a service over the long term. The calculated score measures the sample, rather than establishing certainty about every future case.

9. Common mistakes and revision sheet

Avoid four shifts: percentage into intensity, probability into duration, past frequency into future guarantee, and displayed precision into accuracy. Do not add overlapping probabilities. Do not assume that neighbouring periods are independent. Low probability does not cancel a serious consequence; a reasonable decision does not become bad simply because the phenomenon ultimately did not occur.

Revision sheet: define variable, threshold, place and period; distinguish probability from observation; examine calibration

across series; check relationships between events; consider consequences, alternatives and instructions. Read a range and a probability together with their definitions. No calculation in this chapter produces a current forecast or safety authorisation.

10. Checked primary references

National Weather Service, “Precipitation probability”, educational factsheet: https://www.weather.gov/media/pah/WeatherEducation/pop.pdf . Definition and reading limitations of the American product, without generalising its threshold to every service.

Met Office, “Using ensemble forecasts in decision-making”: https://www.metoffice.gov.uk/research/weather/ensemble-forecasting/decision-making ; “How to use our long-range predictions”: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/seasonal-forecast/user-guide . Consulted for the French manuscript on 11 October 2026. Series, costs, exercises and calculations are fictional creations; only one eight-word verbatim quotation from the first page is used.

CHAPTER 10 - Vigilance, warnings and decisions: hazards, exposure and responsible authorities

1. A phenomenon and its consequences are different things

Heavy rain is a meteorological phenomenon; the damage it may cause also depends on the place, what is present there and the means of protection. A rainfall amount does not lead directly to one unique human consequence. Terrain, soil conditions, drainage networks, buildings and activities alter the situation. A risk description must connect several elements rather than reduce everything to one number.

Here, a hazard is a phenomenon capable of causing damage. Exposure means the presence of people, property or activities in an affected area. Vulnerability concerns conditions that make them more sensitive to that hazard's effects. Capacities include resources that can prevent or limit some consequences. These distinctions draw on UNDRR's institutional terminology; they organise analysis rather than automatically calculate a universal score.

In a fictional example, two book stores receive the same outdoor rain. The first is in a low-lying room where water may enter; the second is in a suitable, maintained building. The phenomenon's intensity is comparable, but possible consequences differ. This does not certify the second building's safety without investigation. The example only shows why the place's characteristics matter.

We must also avoid making individuals solely responsible for their vulnerability. Access to housing, transport, information or material resources influences protective options. An identical instruction may be harder to follow for an isolated or dependent person.

Understanding this difference makes preparation more realistic; it does not give a guide the power to replace the responsible services.

2. Forecast, vigilance and alert: three functions

A forecast describes expected meteorological development, with its uncertainties. Vigilance information draws attention to a potential hazard and its possible consequences within an area. An alert transmitted by a responsible authority addresses a situation requiring protective measures or behaviour. These functions complement one another but must not be confused.

Météo-France explains that its vigilance supplements forecasts and may lead authorities to activate an alert procedure. In mainland France, its presentation uses four colours and territorial information for the current day and the following day. A colour must be read together with the phenomenon, period and associated bulletins. It is neither a temperature, a raw probability nor an identical instruction for every situation.

The ministry's presentation also distinguishes anticipating danger from alerting the population. Authorities may transmit appropriate instructions: their content depends on the phenomenon and context. We must therefore neither infer an evacuation order ourselves from one colour nor disregard a local instruction because a general chart looks reassuring. More specific information may address a different scale.

A system's structure varies between countries and territories. Some areas have particular arrangements, notably for cyclones or flooding. French terminology is insufficient to interpret every international warning. Before travelling, identify the meteorological service and responsible authorities for the place concerned. This

chapter describes principles and references rather than their current status.

3. Reading complete information, not just its colour

A rigorous reading begins with the provider and update time. It then identifies the area, phenomenon, start and end of validity, followed by consequences and associated advice. An old screenshot may retain convincing graphics while no longer being relevant. If its date is cropped out, an essential element is missing.

Geographical limitations must also be examined. District-level information does not necessarily describe every street, valley or route in the same way. Conversely, one local observation is insufficient to invalidate information about a wider territory. Seeing a calm sky directly ahead does not prove there is no danger on a road or during the following period.

A vigilance level may depend on the territory's sensitivity rather than only an identical weather threshold everywhere. Infrastructure or an activity may be disrupted by conditions that are relatively ordinary elsewhere. Readers must therefore not compare two colours as though comparing two universal measurements of strength. They must examine the described reasons and consequences.

Rain forecasts and flood information also answer different questions. Rain falls across an area over a duration; water may subsequently move and accumulate within a catchment. Flooding cannot be reduced to rain observed where one stands. Specialist services supply information that cannot be reconstructed with a simple thermometer or a glimpse of the sky.

For a school study, prepare an empty reading sheet: organisation, publication, validity, territory, phenomenon, level, consequences, instructions and next known update. Fill it with an old document

clearly identified as an exercise. Never let this educational sheet be confused with an active warning.

4. Distinguishing local observation from an instruction's authority

A local observation may help explain what is happening. It does not confer competence to decide for an entire population. Authorities and services use other data, know the infrastructure and can coordinate resources. Their instruction must not be replaced by an improvised conclusion based on one sign.

In a fictional situation, someone sees the wind decreasing and wants to reopen a suspended outdoor activity. This observation may be correct at that instant. Nevertheless, the forecast development, site's condition and manager's instructions are missing. A temporary decrease does not establish that danger has ended. Good reasoning identifies missing information instead of converting relief into authorisation.

France's Ministry of the Interior presents FR-Alert as a way to send people in an area messages containing protective instructions. Its page states: “Respectez ces consignes”, meaning that these instructions should be followed. This three-word French quotation emphasises the authority of protective instructions. The ministry also describes sirens and institutional media as complementary means. The guide guarantees neither receipt of a message on every phone nor operation of every channel in a particular situation. Preparing several information channels is more cautious than relying on one app.

If an alert is received, read its authority, area and instructions; follow the appropriate official directions. Do not turn a forwarded message or an undated video into a new alert. Checking information means returning, when possible without putting

oneself in danger, to its official source and context. This does not justify delaying a clear instruction in an urgent situation.

5. Constructing a decision before a difficult situation

Useful preparation defines criteria before the cost of changing plans becomes too high. Imagine an association planning an outdoor exhibition of fragile documents. It can identify an indoor venue, responsible person, decision time and way to inform the group in advance. This organisation does not prevent rain, but limits confusion.

A postponement criterion must rely on information appropriate to the activity and the responsible manager's requirements. This guide supplies no wind or rain threshold universally authorising an event. An installation's weight, terrain, participants and applicable rules change the situation. A fictional school threshold cannot be copied as a real protocol.

A decision has several dimensions: what is known, what is missing, what can be changed and when a choice is necessary. A continuation scenario, adaptation scenario and postponement scenario can be prepared. Scenarios must not conceal identical exposure behind three different names. If an alternative does not actually reduce risk, it fails to supply the expected protection.

The decision must then be communicated clearly. “The event is moved indoors according to the manager's instruction” is more precise than an ambiguous message leaving everyone to guess. The document must give an appropriate place, time and contact person. During a real alert, official instructions take priority over the planned programme; preparation does not turn an organiser into an emergency authority.

6. Why vigilance information may not be followed by the expected phenomenon

The information concerns a development that is still uncertain. A phenomenon may shift, be less intense or have different consequences. An absence of events at an individual's location does not necessarily demonstrate an error across the whole area. Nevertheless, this does not make evaluation useless: services must examine what was forecast and observed at relevant scales.

False alarms and missed events are different situations. Excessively frequent, poorly relevant information may lead to reduced attention. Infrequent information may leave hazards without preparation. This trade-off must be studied using observations, consequences and clearly defined objectives. It cannot be resolved simply by wanting to be right every time about an isolated case.

Evaluation afterwards must not confuse the outcome with the initial decision's quality. If an association moved its exhibition because a danger was announced and no rain ultimately occurred, the decision may have been justified by available information. To examine it, reconstruct what was known when the choice was made rather than only what is known afterwards.

Another mistake is treating a historical performance assessment as a personal guarantee. A service may show good statistics without ensuring that no future event will be missed. Readers must remain attentive to local signs, updates and instructions. Neither absolute trust nor systematic rejection: a source's quality justifies its use, with its limitations.

7. Information, rumour and collective responsibility

A weather rumour often has three attractions: urgent wording, a striking image and a simple conclusion. These qualities do not prove its truth. A video of an old event may be presented as current; a chart of an extreme scenario may become a certain forecast in a forwarded message. A change in context is enough to turn real information into a misleading claim.

Before sharing, check the provider, date, place, variable and status. Is it a forecast, observation, illustration or exercise? Essential uncertainty must not disappear from a summary. When checking is impossible, do not present the message as an official instruction. You can identify uncertainty without spreading a confident assertion.

Collective responsibility also includes accessibility. Information may be official but difficult to understand for someone unfamiliar with the vocabulary or language. We can help read terms, identify the source and convey the instruction faithfully. We must not invent a clinical adaptation or a contradictory instruction. Preparation for particular needs is undertaken with the appropriate contacts before an event.

The offline guide can support this understanding of vocabulary. It does not know whether vigilance is active today, whether a road is open or whether an authority has changed its instructions. Appropriate use consists of learning the distinctions, then consulting the updated information needed when deciding.

8. Fictional case study: postponing an observation outing

A class wants to observe clouds from an authorised terrace. The day before, the manager receives information announcing a risk of a dangerous phenomenon during the planned period. Yet a photograph taken that morning shows a clear sky. How can the analysis be organised without claiming to produce a new forecast?

First step: identify relevant information, its provider, validity and area. Second step: understand the establishment's and manager's instructions. Third step: consider an equivalent indoor activity, such as comparing dated photographs or analysing an exercise chart. Fourth step: communicate the change and explain that one instantaneous photograph does not describe the whole period.

Postponement does not prove exact knowledge of what will happen. It expresses a cautious decision within an organisational framework. The indoor exercise can retain the educational objective without retaining exposure. Afterwards, available data can be analysed to understand developments, but initial information must not be rewritten as though the result had been known.

9. Progressive exercises with worked answers

Exercise A - Intense rain falls in an area without exposed people or property. Is the potential damage the same as in an inhabited area? Answer: no. The phenomenon remains, but exposure and consequences differ. This does not mean an uninhabited area has no ecological importance or that indirect effects are impossible.

Exercise B - A chart is coloured, but its date has been cropped out. What information is missing? Answer: publication, validity period and possibly the distinction between observation and forecast. Without them, the document cannot support a reliable current

decision. Seek the complete source rather than assuming that an image received today was produced today.

Exercise C - Why does a calm observation not automatically cancel vigilance information? Answer: it concerns one point and instant, whereas vigilance concerns a possible phenomenon across an area and duration. The observation is useful data; it does not answer the whole question. Updates and instructions remain necessary.

Exercise D - A forwarded message says “evacuate”, with no authority, place or date. How should it be treated? Answer: do not present it as a verified official instruction. Identify the source and seek appropriate directions. This exercise does not authorise ignoring a clear official alert or undertaking a check that would expose someone to danger.

Exercise E - Prepare three alternatives for our book exhibition. Suggested answer: continuation only under criteria established by the manager; moving indoors if this option is truly suitable; postponement if no acceptable solution is available. Specify who decides and how the public is informed. No invented meteorological threshold is added.

Exercise F - An announced situation did not occur outside your house. Write a measured conclusion. Suggested answer: the event was not observed at this point; evaluating the information requires examining the area, period and corresponding observations. This case proves neither perfection nor general uselessness of the system.

10. Revision sheet and references

Revision sheet: phenomenon, exposure, vulnerability and capacities contribute to consequences. A forecast describes; vigilance draws attention to a hazard; an alert transmits an authority's instructions. Read the provider, date, validity, area, phenomenon and advice. Prepare alternatives before deciding. Replace neither specialist services nor an official instruction with an isolated colour, photograph or local AI response.

UNDRR, institutional terminology “Hazard”, “Exposure”, “Vulnerability”: https://www.undrr.org/terminology/hazard ; https://www.undrr.org/terminology/exposure ; https://www.undrr.org/terminology/vulnerability . Météo-France, “5 questions sur la Vigilance météorologique”, 7 July 2026: https://meteofrance.com/vigilance-et-securite/5-questions-sur-la-vigilance-meteorologique .

France's Ministry of the Interior, “Système d'alerte des populations”: https://www.securite-civile.interieur.gouv.fr/reagir/comment-se-preparer-face-aux-risques/systeme-dalerte-des ; ministry responsible for ecological transition, dossier on intense rain and flooding, updated on 2 September 2026: https://www.ecologie.gouv.fr/dossiers/comprendre-risques-naturels-sen-proteger/savoir-pluies-intenses-inondations-france . Consulted for the French manuscript on 11 October 2026. No current vigilance status is reproduced; examples and exercises are fictional, with only one three-word verbatim French quotation from the Ministry of the Interior.

CHAPTER 11 - Activity safety: postponement criteria and the need for updated data

1. Learning meteorology is insufficient to authorise an activity

Knowing how a thunderstorm forms or how to read a pressure improves understanding. It does not automatically confer the competence to decide that an exposed activity is safe. The choice depends on terrain, equipment, people, applicable rules and current information. A general guide supplies concepts; it replaces neither a trained manager nor a specialist service.

This chapter aims to prepare good questions. Which variable matters for the activity? At what place and over what duration? What consequences are possible? Which document supplies appropriate information? Who may decide to continue, modify or postpone? An answer ignoring these questions may mislead even when it uses correct scientific words.

An educational activity without exposure must be distinguished from a real outdoor activity. Calculating the delay between lightning and thunder from a recording allows sound propagation to be studied; waiting outdoors to make that calculation during a thunderstorm is an entirely different situation. This guide does not recommend the second use. The numerical examples below are exercises, never thresholds authorising a practice.

Preparation also means accepting an alternative. Postponement may preserve a project rather than make it fail. Cloud observation can be replaced by analysis of dated photographs; a drawing exhibition can move to a suitable venue. The alternative must

retain an objective without retaining dangerous exposure in another form.

2. Identifying variables useful for the activity

Mean wind and gusts describe different things. The first summarises a measurement period according to a method; the second concerns briefer variations. An activity sensitive to a sudden force cannot be assessed using only the mean. The forecast's altitude, exposure and location must also be known. A near-ground value across a general area does not describe every ridge or corridor.

Rain amount and intensity must also be separated. Twenty millimetres over a day and twenty millimetres within a few minutes have different temporal distributions. Consequences also depend on the ground and flows. A simple accumulation cannot establish the condition of a road, basement or watercourse.

Air temperature does not describe all thermal exposure. Sun, wind, humidity, duration and activity matter. Specialised indices have definitions and limitations. Choosing one number in an app to diagnose a person or guarantee that exertion is appropriate would be incorrect. Official health advice and competent professionals address dimensions different from this scientific course.

Visibility is distinct from cloud cover. Many clouds may be visible while horizontal visibility remains good; fog may instead greatly reduce it near the ground. An image of the sky does not necessarily describe what a driver or walker will encounter along a route. Identifying the variable avoids answering a question with a neighbouring but insufficient indicator.

3. A preparation checklist without invented thresholds

Construct a checklist with five headings: activity and place; complete period; necessary information; decision and alternatives; updates and communication. It should be short and understandable to its users. These headings organise reasoning; they do not constitute a universal safety protocol.

Under the first heading, state what will actually be done. “Outing” is too vague: a supervised walk, equipment installation, road journey and sailing do not raise the same questions. Under the second, include preparation and return rather than only the central moment. An activity planned from 14:00 to 15:00 may require travel before and after that period.

Under the third heading, list relevant documents and their sources. A specialist forecast, vigilance information, official site status or manager's instruction may be needed. Under the fourth, specify who decides and what replacement solution is possible. Under the fifth, plan when to consult new information and how to inform the group. The most recent consultation does not remove the need to follow an instruction received afterwards.

If essential data are missing, do not fill the gap with a reassuring estimate. Modifying or postponing the project may be necessary. “No warning has reached me” proves neither that all information has been consulted nor that no hazard exists. The checklist helps recognise this gap rather than conceal it.

4. Mountains: general information is insufficient

Terrain transforms conditions: altitude, slope, exposure and valley configuration matter. A forecast for a nearby town does not directly describe a high-altitude route. The sky may develop differently on two slopes, and ground conditions add their own difficulties. The difference cannot be corrected simply by applying a formula to a temperature.

In snowy mountains, avalanche danger depends particularly on the snowpack and terrain rather than only current temperature. Météo-France presents specialist bulletins and emphasises that a risk index alone is insufficient. Reading them requires appropriate additional information and the participant's or supervisor's skills. A visible track is not evidence of safety.

The official presentation notes that the European avalanche danger scale was adopted across the Alpine region in 1993. This reference shows a search for shared language between services; it does not turn a scale number into permission for every slope. A regional summary and a local decision are not interchangeable.

This guide teaches neither a crossing technique, a rescue method nor a rule guaranteeing a route. Consult current bulletins, authorities' and sites' instructions, and mountain professionals when the project requires them. Pressure and temperature-gradient examples from previous chapters help explain concepts rather than certify conditions for an activity.

5. Sea and coast: wind, waves and territory

A land forecast does not fully answer a maritime question. Wind, sea state, swell, tide and currents concern distinct processes that may interact. Wind direction at one place does not establish every wave observed there. A temporarily calm sea does not necessarily describe expected development across an entire outing.

Météo-France explains that it produces regular bulletins and special marine safety bulletins, broadcast notably by France's CROSS rescue coordination centres within their responsibilities. This organisation provides specialised information; the guide reproduces neither radio frequencies, schedules nor navigation criteria as though they were universal and permanent. Real use requires current documents and the necessary skills.

On the coast, observation activities may also be exposed to waves and changing conditions. No rain is not a safety indicator on a jetty or breakwater. A closure, prohibition or local instruction must be respected; this text proposes no route for bypassing it.

For a school study, compare a fictional wind bulletin with a fictional swell bulletin. Identify units, direction, period and area. The exercise demonstrates the need for several variables; it does not produce an operational decision. For a real outing, the organiser must rely on appropriate information and responsibilities rather than delegate the decision to a general-purpose AI response.

6. Thunderstorms: do not wait for proof of proximity

The National Weather Service summarises a principle in the short phrase “When Thunder Roars, Go Indoors”. This five-word quotation reminds us that hearing thunder is not encouragement to continue an outdoor observation. Its official page states that no outdoor location is safe when thunderstorms are in the area. Detailed protective measures must be read in the responsible recommendations rather than improvised from a sound delay.

A spectacular photograph may encourage someone to wait for the next flash. An educational aim does not justify this exposure. Use recordings or exercises conducted under appropriate conditions. The lightning chapter explains a mechanism; it offers no method for approaching a thunderstorm or determining a safe distance.

An outdoor activity should have an appropriate procedure defined in advance by its managers: information, suspension and a replacement option. This guide sets no universal resumption time. A clearer sky, saved radar image or lack of thunder for a few minutes does not replace the necessary rules and updates.

The same logic applies to a group observation. Before any real activity, the supervisor identifies protective conditions and relevant information. If this framework does not exist, it must not be replaced by a rule obtained from a local assistant at the last moment. Scientific learning can continue perfectly well without placing anyone in an exposed situation.

7. Travel and everyday activities

Travel has its own constraints: road condition, visibility, traffic, closures and available resources. A rain forecast cannot assure that a road is passable. A calm starting point does not exclude difficulties on another part of the journey. Appropriate information must be consulted and official restrictions followed.

For flooding or intense rain, the ministry's dossier particularly reminds readers to postpone journeys and avoid crossing dangerous places such as fords or low-water crossings. This principle must not be turned into a depth test performed by the reader. The guide supplies no water depth that permits crossing on foot or in a vehicle.

In everyday life, preparing clear information may avoid a rushed decision. A family can agree on how to communicate a programme change; an association can indicate an alternative meeting venue; an establishment has its own instructions. These arrangements do not ensure network or transport operation, but limit misunderstandings.

People with particular needs may require tailored preparation with the appropriate contacts. This text diagnoses no individual capacity and prescribes no care. It invites readers not to assume that everyone has the same means of travelling, understanding a message or changing plans quickly.

8. Preparing information when connectivity is missing

A downloaded document remains readable offline, but a saved forecast or warning does not update itself. Local access is useful for learning terms and retrieving a prepared procedure. It does not guarantee knowledge of the current situation. Keep dates visible on documents whose validity depends on time.

If an activity requires recent data, lack of connectivity becomes information about your ability to decide. It does not mean that danger is zero. Seeking another channel planned by the organiser or postponing may be necessary. No offline assistant should present a general description as a current bulletin.

In a fictional exercise, an outing depends on specialised information updated that morning. The network is unavailable and no other planned source can be accessed. The conclusion cannot be “the last chart was favourable, so we are leaving”. It must acknowledge the gap, consult the manager and apply pre-established criteria. A project's value does not justify inventing its missing data.

Preparation finally means keeping information accessible: explicit titles, readable dates, appropriate contacts and short instructions. A library full of files without reference points may slow consultation. Contents and document classification facilitate access to knowledge; they do not automatically make consulted content current.

9. Progressive exercises with worked answers

Exercise A - A fictional event runs from 15:00 to 16:00, with setup at 13:00 and return planned for 18:00. What period should be examined? Answer: the entire exposed period, from setup to return, accounting for journeys and their duration. The public event period alone does not summarise information needs. The exercise defines no continuation threshold.

Exercise B - An app displays a moderate mean wind. Can the absence of strong gusts be inferred? Answer: no. The variables differ. Appropriate information must be read together with its units, place and period. A mean is not a ceiling for every variation.

Exercise C - A village is at a different altitude from the planned route. Is a simple temperature correction enough? Answer: no. Terrain, exposure, wind, visibility and ground conditions add differences. A school relationship can help explain a mechanism without replacing a specialist forecast or supervised decision.

Exercise D - Why is an avalanche index's colour insufficient? Answer: it summarises a hazard at a defined scale. Snowpack conditions, terrain, development and skills remain relevant. The guide does not propose an interpretation that automatically authorises a slope. Official instructions and competent professionals must be considered.

Exercise E - A local document bears an old date while the activity requires current information. What should be concluded? Answer: the document retains educational or historical value, but does not meet the need for updating. Seek an appropriate channel and apply the manager's criteria; do not turn a lack of new data into confirmation of the old data.

Exercise F - Prepare a postponement message for a fictional activity. Suggested wording: “Tomorrow's observation is replaced

by an indoor session following the supervisor's decision. The place and time are in the updated programme. We will analyse recorded documents; this session requires no observation of a dangerous phenomenon.” The message must correspond to a real decision before being used.

Exercise G - An installation can be moved, but the new location retains identical wind exposure. Is this a protective alternative? Answer: not for the hazard considered. Changing a place's name does not automatically change conditions. Analysis must check the alternative's real effect without inventing protection.

10. Common mistakes, revision and references

Do not confuse equipment with a guarantee, experience with current knowledge, or momentary calm with no future danger. Do not infer ground conditions solely from atmospheric weather. Do not use a course calculation as an operational threshold. Costs or effort already invested in a project do not remove unfavourable information. Preparing an alternative preserves the objective without retaining exposure.

Revision sheet: define the activity, place and complete period; identify variables and specialist services; know responsible people and instructions; plan continuation, adaptation or postponement using appropriate criteria; check updates; recognise missing data. Offline reading helps learning and retrieving reference points, never certifying current weather.

Météo-France, “Avalanche : quels dangers, comment réagir et s'informer ?”, 5 February 2025: https://meteofrance.com/vigilance-et-securite/avalanche-quels-dangers-comment-reagir-et-sinformer ; “Météo-France et la mer”, 8 June 2026: https://meteofrance.com/meteo-a-z/meteo-france-et-la-mer . National Weather Service, “Lightning safety”: https://www.weather.gov/safety/lightning-safety .

Ministry responsible for ecological transition, dossier on intense rain and flooding: https://www.ecologie.gouv.fr/dossiers/comprendre-risques-naturels-sen

-proteger/savoir-pluies-intenses-inondations-france . Primary sources consulted for the French manuscript on 11 October 2026. Only one five-word verbatim National Weather Service quotation is used in this chapter; examples and exercises are original. No current weather information or healthcare procedure is supplied.

CHAPTER 12 - Weather notebooks and synthesis exercises: observing, comparing and recognising limits

1. A notebook for learning, without manufacturing a forecast

A weather notebook collects dated observations described according to a method. It connects the guide's concepts with data, allows a variation to be examined and helps recognise what is unknown. Its mere existence makes it neither an official station nor a warning system. A few local measurements cannot forecast every condition along a route, across a territory or during an exposed activity.

The educational objective must be defined before choosing columns. Do you want to study temperature variations at fixed times, compare cloud descriptions or understand the difference between accumulated rain and intensity? A precise question requires appropriate data. A long list of information without provenance may create an impression of mastery while preventing comparisons from being checked.

Work can take place entirely indoors using recorded data, captioned historical photographs or explicitly identified fictional series. Direct observation never requires exposure to a dangerous phenomenon. If an instruction or conditions make the activity inappropriate, use an indoor session or postpone according to the responsible people. Completing a table does not justify going outside during a hazard.

Cloud descriptions show the value of shared vocabulary. The World Meteorological Organization notes Luke Howard's role: in 1803 he

proposed a classification, some of whose names have been retained and developed. This historical reference does not establish that a beginner can identify every formation without hesitation. It explains why a defined category and reproducible description are more useful than an isolated personal impression.

2. Designing a traceable observation sheet

A first line describes the series: question studied, useful approximate location, period, method and provenance. For a school exercise, do not record personal data unnecessarily. An observation-point identifier may be sufficient. If precise location is necessary for a supervised scientific analysis, it must be handled under the project's rules; the guide does not request publication of a private address.

Each reading carries a date, time and time-zone indication. Distinguish measurement time, publication time and the time when you saved the data. A bulletin published at noon may contain an observation from eleven o'clock. A forecast published today may concern tomorrow. The “type” column may contain observation, saved forecast or fictional data. Mixing these without distinction makes interpretation confusing.

For every variable, give units and method. Temperature in degrees Celsius is not energy; pressure in hectopascals is not altitude; rain amount in millimetres is not speed. Specify periods for accumulations and averages. Mean wind speed over an interval and a maximum gust answer different questions. Units alone do not define the entire measurement.

Add a quality column: data available, missing, estimated, corrected or method changed. An absent value does not become zero. A correction must not erase the initial value without a trace: retain the reason and version useful for comparison. For a fictional series,

state that provenance clearly in the title and in tables that might be copied separately.

3. Comparability, instruments and location

An instrument converts a quantity into an indication according to its operation. Resolution describes the step or displayed detail; accuracy concerns closeness to a reference value under defined conditions. Displaying two decimal places does not prove a measurement accurate to a hundredth. Operation, calibration, location and conditions of use remain decisive. A visual estimate can be useful if identified as such.

Comparing two temperatures requires knowing how they were measured. An instrument exposed to radiation, a heated surface and an instrument intended to measure air do not automatically describe the same quantity. Suitable shielding or a shelter may limit some effects, but does not alone guarantee an absence of every bias. For a genuine measurement network, follow the responsible service's methods and requirements; a home exercise must present its limitations.

A change in location may create a break in a series. Suppose an instrument moves from a ventilated place to an area near a wall. A rise observed after this change does not prove climate development. Method and surroundings have also changed. Record the break, compare only what can be compared and avoid turning a local change in setup into a general trend.

The same applies to times. Comparing nine o'clock one day with fifteen o'clock the next combines variation between days with variation within a day. To study changes at a fixed time, choose a consistent method and record departures. Do not arbitrarily correct a value to resemble the preceding one. Scientific quality comes

from traceability and examination, rather than an artificially regular table.

4. Describe before interpreting

Separate a column for findings from a column for hypotheses. “A cloud layer appears in the eleven-o'clock photograph” describes what is observed, with the image's limitations. “It necessarily announces rain within an hour” adds a conclusion not justified by that photograph alone. A hypothesis must be labelled as such and specify information that could support or contradict it.

Describe clouds using cautious categories: appearance, apparent extent, development across dated images, and probable genus when criteria are visible. A limited perspective does not always establish height. A sky hidden by a building must not be recorded as entirely clear. When several identifications are possible, record doubt instead of choosing decorative certainty.

For wind, leaves or visible objects supply clues, but not necessarily a speed measured at a standardised height. Local movement may depend on terrain or obstacles. If an appropriate measurement is unavailable, use an identified qualitative description. An approximate conversion must not be displayed as an instrumental measurement.

Interpretation then links several pieces of information: temperature, humidity, pressure, clouds, development and context. Bringing them together does not permit an automatic conclusion. The mechanisms studied provide possibilities and conditions; sufficient data are still necessary. A serious notebook may conclude “insufficient information to decide”. This answer is more useful than an invented prediction that fills every box.

5. First calculations on a fictional series

Consider four fictional temperatures: 9 °C at eight o'clock, 11 °C at eleven, 14 °C at fourteen and 12 °C at seventeen. Their arithmetic mean is (9 + 11 + 14 + 12) / 4 = 11.5 °C. It describes these four samples. It does not automatically become the whole day's mean, because other hours were not observed and the official averaging method is unspecified.

The minimum of the four values is 9 °C and maximum 14 °C; their range is 5 °C. These are the sample's minimum, maximum and range. Writing “daily minimum temperature: 9 °C” would be unjustified if the night was not measured. Between eleven and fourteen o'clock, the difference is 3 °C over three hours, an average change of 1 °C per hour. This average does not describe every minute.

For a fictional cumulative rainfall series, the counter reads 2 mm at eight o'clock and 5 mm at noon. If the device has not been reset and values are comparable, the additional accumulation is 3 mm over four hours. The mean rate over this interval is 0.75 mm per hour. It proves neither continuous rain nor a maximum intensity of 0.75 mm per hour: the 3 mm may have fallen unevenly.

If a reset occurred at ten o'clock, directly subtracting the two indications loses its meaning. Values before and after the operation are needed, or we must acknowledge that accumulation cannot be reconstructed from available data alone. This example shows why metadata form part of measurement. An exact calculation applied to incomparable data produces a false conclusion.

6. Graphs, trends and missing data

A graph must display a title, axes, units and a period. If observation times are irregular, their positions must reflect that irregularity on a time axis. Four points equally spaced on the page may suggest identical intervals. A line between two observations is a graphical connection; it does not prove that every intermediate value was measured.

When the eleven-o'clock value is missing, do not silently replace it with an interpolated value. Interpolation proposes an estimate based on an assumption about variation. It may serve an exercise, but must be distinguished from observation. The mean of remaining values concerns a different sample. Comparing days with different measurement periods therefore requires particular care.

Three successive warmer days do not alone establish a climate trend. Duration, variability, method and context must be examined. A trend concerns an appropriate body of data and method of analysis. A short notebook can document a local episode, rather than automatically represent an entire region or global climate. This limitation does not cancel its value for understanding variations and learning a method.

Also avoid choosing a scale that exaggerates or conceals a difference without explanation. An axis starting at 10 °C may make a small variation visible, but must remain clearly graduated. A large coloured area does not replace values. When comparing two graphs, check scales before interpreting shape. Presentation should help explain what was measured rather than create a predetermined impression.

7. Reading pressure, humidity and forecasts together

A fictional pressure falls from 1,014 hPa to 1,008 hPa between readings at the same point using the same method. The difference is −6 hPa. This finding does not automatically announce a particular phenomenon. A forecast particularly requires spatial and temporal context, system development and other variables. Also check whether values are local pressures or reduced to sea level: comparing them is not always straightforward.

Suppose a temperature of 12 °C and dew point of 8.3 °C. Their difference is 3.7 °C. It provides information about proximity to certain saturation conditions, but cannot alone forecast fog formation at a given place and time. Cooling, mixing, moisture inputs and local conditions matter. A hypothesis may be studied using additional data; it must not become an established result.

Record forecasts separately so they can later be compared with observations without retrospectively changing their content. A forecast sheet includes provider, issue date, place, lead time, variable and definition. A precipitation probability cannot be compared directly with an amount in millimetres. A forecast mean and an observed maximum are not two expressions of the same measurement.

For verification, choose the rule before examining the outcome. In an exercise, you might measure the difference between forecast and observed temperature at a defined time. If you later change the time to obtain a smaller difference, you are no longer checking the initial question. Documenting an error is not an educational failure: it allows data, definitions and forecast limitations to be examined.

8. Synthesis workshop with worked answers

Exercise A - A fictional series supplies 10, 13 and 16 °C at three times. Calculate mean and range, then state a limitation. Answer: mean 13 °C; range 6 °C. These calculations concern the three values. Without measurements at other times, the whole day's mean or extremes cannot be announced. State the limitation in the caption rather than forgetting it after calculation.

Exercise B - An accumulation changes from 4 to 10 mm over two hours, without a reset. What can be established? Answer: 6 additional millimetres and a mean rate of 3 millimetres per hour. Neither each episode's exact duration nor its maximum intensity is known. Intermittent rain may produce the same accumulation as steadier rain. Finer observations are needed to distinguish them.

Exercise C - A table says “rain: zero” where the sensor transmitted no data. Correct it. Answer: replace the value with missing data and record the known incident. Zero asserts a measurement; no transmission does not establish it. If another source is used, its provenance and comparison conditions must appear. Two methods must not be discreetly mixed to complete the series.

Exercise D - Fictional temperature forecasts are 12, 14 and 13 °C; corresponding observations are 11, 15 and 13 °C. Calculate forecast-minus-observation differences and the mean of their absolute values. Answer: +1, −1 and 0 °C; absolute mean (1 + 1 + 0) / 3, approximately 0.67 °C. The signed mean is zero, but conceals two nonzero differences cancelling one another.

Exercise E - Two groups compare readings. The first measures air at fixed times; the second records a surface temperature whenever it can access the place. Can they conclude that one neighbourhood is warmer? Answer: variables, times and methods differ. This comparison alone does not justify the conclusion. A shared

question and comparable measurements must be defined, or the two series retained as observations of different phenomena.

Exercise F - An app contains an old chart whose date is no longer visible after copying. An outing requires current information. What use is legitimate? Answer: the chart may serve historical analysis if its provenance is recovered. It cannot confirm current conditions. Seek dated official information and follow instructions; do not treat the absence of a new warning in the file as proof of safety.

Exercise G - Among twenty fictional days forecast with a rain probability of 50%, twelve contain the defined event. Is the forecast definitively poor? Answer: twelve out of twenty is 60%, but a small set fluctuates. The definition, comparable cases and a sufficient series must be examined. A particular difference alone establishes neither poor calibration nor guaranteed good calibration. The result remains an observation to incorporate into analysis.

Exercise H - Formulate a notebook conclusion without forecasting tomorrow. Suggested wording: “Across the four observed times using the same method, temperature first increased and then decreased. Missing night-time values prevent determination of daily extremes. The series describes this point and period; it cannot alone establish a climate trend.” This conclusion connects result, method and limitation without claiming more.

9. Three further difficulties: uncertainty, angles and conversion

A comparison may concern values accompanied by uncertainty known within an exercise. Suppose two fictional temperatures: 9.7 °C followed by 10.5 °C, each with an absolute error bound of 0.3 °C. The first value is then compatible, under this assumption, with an interval from 9.4 to 10.0 °C; the second with 10.2 to 10.8 °C. The rise lies between 0.2 and 1.4 °C if the stated bounds actually cover the errors considered.

The difference between indications is 0.8 °C, but its precision must not be presented as infinite. Reasoning about bounds used the unfavourable cases: highest initial value and lowest final value, then the reverse. This calculation supplies no probability of a rise. An error bound, standard deviation and confidence interval are not interchangeable expressions. The method defining them must be known before their numbers are used.

If the same instrument has a constant bias, part of that bias may disappear in a difference. However, assuming every effect is constant without checking is unjustified. Movement, changing radiation or a modified method may also matter. An educational notebook's purpose is not to produce a sophisticated correction without data; it is to show assumptions and promise no more precision than measurement supports.

Angles introduce another difficulty. Two directions close to north, 350° and 10°, must not be averaged like two temperatures. The ordinary arithmetic mean gives 180°, south, although the directions lie on either side of north. Angles are periodic: 360° and 0° identify the same direction. An appropriate analysis may represent directions as vectors, then examine their sum and its length.

In this fictional example, two equally weighted unit vectors placed symmetrically on either side of north have a sum pointing north. This construction is not a universal procedure for averaging real wind: speeds, durations and the provider's method must also be specified. Two exactly opposite, equally weighted directions would have a zero sum; announcing a well-defined mean direction would then be misleading. Finally, check the convention: a meteorological wind direction usually indicates where it comes from rather than where it goes.

Unit conversion must also respect the quantity. To convert a temperature in degrees Celsius into degrees Fahrenheit, the relationship is T°F = 1.8 × T°C + 32. Thus, 20 °C corresponds to 68 °F. A temperature difference of 3 °C, however, corresponds to a difference of 5.4 °F: 32 is not added. The constant concerns the scale's origin rather than every change. Distinguishing a value on a scale from a difference prevents this mistake.

Additional exercise - Two fictional temperatures are 8.0 and 8.2 °C, each with error bounds of 0.4 °C. Can a certain rise be asserted within this bounded-error model? Answer: the intervals are 7.6 to 8.4 °C and 7.8 to 8.6 °C. They overlap; the indications and bounds alone cannot determine the real difference's sign. The displayed difference is positive, but the result must retain this limitation.

Additional exercise - A file contains two lines with the same local time, without a complete date or time zone. Can they be ordered with certainty? Answer: not from this information alone. A change of date, time zone or civil time may create ambiguity. Recover the metadata; do not invent an order based solely on line position. This precaution concerns traceability independently of the observed weather.

10. Turning observations into active revision

Construct a synthesis page with four boxes: phenomenon, mechanism, relevant data and limitation. For wind, the mechanism includes pressure gradients, Earth's rotation and friction; relevant data depend on the question-mean or gust, direction and period. The limitation notes that moving leaves alone do not supply all these measurements. For precipitation, distinguish formation, accumulation and temporal distribution.

Add a box labelled “what I must check in current information”. It may contain date, place, validity period, responsible service, type of data and associated instructions. This box must not be completed once and for all from the present guide: it identifies elements to examine when an activity requires them. An offline sheet helps remember the method rather than display current conditions.

To prepare revision, explain to someone why pressure and altitude are different quantities, why relative humidity varies with temperature, why a cloud is insufficient evidence of immediate rain and why a probability is not a duration. Then do a numerical exercise and state the unit. Finally, present one limitation of your answer. This approach checks a stronger understanding than recognising a word.

Reread your notebook with a critical question: could another person understand where my data come from and repeat the calculations? If not, complete the metadata or narrow the conclusion. You can also examine two competing interpretations and specify which observation would distinguish them. The purpose is not to seek certainty in every line, but to learn to match claims to evidence.

11. Common mistakes and final revision sheet

Do not confuse zero with absence, accumulation with intensity, mean with extreme, issue time with validity time, observation with forecast, or short-term weather with climate. Do not erase instrument or location changes. Do not infer a certain cause from simple succession. Do not turn a photograph or local measurement into permission for an exposed activity. The guide replaces no official service or responsible authority.

Final revision sheet: precise question; identifiable provenance; appropriate place and period; explicit units and methods; flagged missing data; checked calculations; result distinct from hypothesis; proportionate comparison; written limitations; current information sought through appropriate channels when needed. A successful notebook may contain uncertainties. It fails particularly when it conceals them beneath numbers or overly broad conclusions.

The whole guide connects energy, pressure, humidity, clouds, fronts, dangerous phenomena, models, probabilities and decisions. None of these elements should become an isolated magical rule. Understanding a mechanism helps ask better questions; recognising what is missing helps avoid misleading conclusions. For offline learning, these abilities complement one another. For a real decision, they must be connected with dated information and the appropriate instructions.

12. References and provenance

World Meteorological Organization, “Classifying clouds”, historical reference to Luke Howard and the 1803 classification: https://public.wmo.int/world-meteorological-day-2017/classifying-clouds ; International Cloud Atlas, genera: https://cloudatlas.wmo.int/en/principles-of-cloud-classification-genera.html . Met Office, observations and their role in meteorological understanding: https://weather.metoffice.gov.uk/learn-about/how-forecasts-are-made/observations .

International Bureau of Weights and Measures, SI Brochure: https://www.bipm.org/en/publications/si-brochure . Primary sources consulted for the French manuscript on 11 October 2026. No third-party verbatim quotation is used in this chapter; all numerical exercise data and notebook situations are fictional and original. No current observation, operational forecast or real-time warning is supplied.