SECTION: Table_of_Contents_Chapter
Chapter title in running head: CHAPTER 14. OBSERVATION OF PRESENT AND …
Chapter_ID: 8_I_14_en
Part title in running head: PART I. MEASUREMENT OF METEOROLOGICAL VARI…

SECTION: Chapter_book
Chapter title in running head: CHAPTER 14. OBSERVATION OF PRESENT AND …
Chapter_ID: 8_I_14_en

# CHAPTER 14. OBSERVATION OF PRESENT AND PAST WEATHER; STATE OF THE GROUND

## 14.1 GENERAL

### 14.1.1 Definitions

In observational practice the term *weather* is regarded as covering those observations of the state of the atmosphere, and of phenomena associated with it, which were initially not intended to be measured quantitatively. These observations are qualitative descriptions of phenomena observed in the atmosphere or on the Earth's surface, such as precipitation (~~hydrometeor~~hydrometeors falling through the atmosphere), suspended or blowing particles (hydrometeors and lithometeors), or other specially designated optical phenomena (photometeor) or electrical manifestations (electrometeor). Detailed descriptions can be found in WMO (~~1975~~2017).

A *hydrometeor* is an ensemble*Hydrometeors* consist of liquid or solid water particles. They may be suspended in~~, or falling through,~~ the atmosphere, fall through the atmosphere, be blown by the wind from the Earth's surface~~,~~ or be deposited on other objects ~~on the ground or in free air~~.

A *lithometeor* ~~is~~consists of an ensemble of particles, most of which are solid and non-aqueous. The particles are ~~more or less~~either suspended in the air~~,~~ or lifted by the wind from the ground.

A *photometeor* is ~~a luminous~~an optical phenomenon produced by the reflection, refraction, diffraction or interference of light from the ~~sun~~Sun or the ~~moon~~Moon.

An *electrometeor* is a visible or audible manifestation of atmospheric electricity.

A special class of weather phenomena are localized weather events. Definitions of such events can be found in WMO (1992). Specific events such as dust whirls and funnel clouds are defined and described in ~~section ~~14.2.3.

In meteorological observations, weather is reported in two forms. *Present weather* (PW) is a description of the weather phenomena present at the time of observation. *Past weather* is used to describe significant weather events occurring during the previous hour, but not occurring at the time of observation.

This chapter also describes the methods of observing a related item, namely the state of the ground. *State of the ground* refers to the condition of the Earth's surface resulting from the recent climate and weather events, in terms of the amount of moisture or description of any layers of solid, or aqueous or non-aqueous particles covering the normal surface.

### 14.1.2     Units and scales

At manned stations, the observations identified as present weather, past weather and state of the ground are reported together with quantitative data. Such observations have been standardized on scales that enable the observer to select an appropriate term from a large number of descriptions derived from the perceptions of human observers and laid down in WMO (2011).

Since 1990, the introduction of automated weather stations has created the need to quantify the functions previously performed by observers. In order to accommodate the varying levels of sophistication and effectiveness of automated meteorological stations in observing present and past weather, specific coding directives have been included in WMO (2011). Because of the complexity of reporting data on present and past weather determined by sophisticated present weather systems, such data should be reported as quantities in binary code format given that the alphanumeric code format suffers from many restrictions in comprehensive reporting.[1]

### 14.1.3     Meteorological requirements

Present and past weather, as well as the state of the ground, are primarily meant to serve as a qualitative description of weather events. They are required basically because of their impact on human activities and transport safety, as well as for their significance for understanding and forecasting synoptic weather systems. Several other chapters in this Guide deal with related topics. The quantitative measurement of precipitation amounts is described in Part Volume I, Chapter 6, and cloud observations are described in Part Volume I, Chapter 15. Part Volume III addresses includes topics that are specific to aeronautical and marine observations, automated systems, radar and atmospherics.

In this chapter, weather observations of interest in the determination of present and past weather are categorized into three types, namely precipitation (falling hydrometeors), atmospheric obscurity and suspensoids (lithometeors and suspended or blowing hydrometeors), and other weather events (such as funnel clouds, squalls and lightning). Liquid precipitation or fog which leave frozen deposits on surfaces are included in the appropriate precipitation and suspended hydrometeor category.

Other phenomena, such as those of an optical nature (photometeors) or electrometeors other than lightning, are indicators of particular atmospheric conditions and may be included in the running record maintained at each station of the weather sequence experienced. However, they are of no significance in the determination of present and past weather when coding standard meteorological observations, and are included here only for completeness.

### 14.1.4     Observation methods

The only current capability for observing all of the different forms of weather are the visual and auditory observations of a trained human observer. However, given the high cost of maintaining a significant staff of trained observers, a number of Meteorological Services are increasing their use of automated observing systems in primary observing networks, as well as continuing their use for supplementing manned networks with automated observations from remote areas.

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[1] Recommendation 3 (CBS-XII) refers to the requirement "to report observed quantities rather than qualitative parameters for present weather in observation from automatic stations in FM 94 BUFR and FM 95 CREX".

Basic research (Bespalov et al., 1983) has confirmed the possibility that weather phenomena may be determined by the logical analysis of a group of data variables. No single sensor is currently available which classifies all present weather; rather, data from a variety of sensors are used (such as visibility, temperature, dewpoint, wind speed and the differentiation of rain versus snow) to make such determinations. Automated observing systems have the capability to perform this logical analysis, but they vary in their ability to observe the required weather phenomenon, based on the instrumentation included in the system and the sophistication of the algorithms. While automated systems cannot observe all types of weather event, those of significance can be observed, making such systems cost-effective alternatives to the fully trained human observer.

## 14.2     OBSERVATION OF PRESENT AND PAST WEATHER

The observations to be recorded under the present weather and past weather headings include the phenomena of precipitation (rain, drizzle, snow, ice pellets, snow grains, diamond dust and hail), atmospheric obscurity and suspensoids (haze, dust, smoke, mist, fog, drifting and blowing snow, dust or sandstorms, dust devils), funnel clouds, squalls and lightning.

When observing present weather, it is necessary to note the various phenomena occurring at the station or in sight of the station at the time of observation. In synoptic reports, if there is no precipitation at the time of observation, account is taken of the conditions during the last hour in selecting the code figure.

### 14.2.1     Precipitation

#### 14.2.1.1  Objects of observation

The *character of precipitation* can be defined as being one of three forms, namely showers, intermittent precipitation and continuous precipitation. Showers are the precipitation events associated with physically separated convective clouds. Observers (or instruments replacing humans) also have to classify precipitation into the three intensity categories, namely ~~light~~slight, moderate and heavy, according to the rates of precipitation fall or other related factors (such as visibility).

The *type of precipitation* (for example rain, drizzle, snow, hail) is the third major observable of precipitation. Observations of rain or drizzle at low temperatures should distinguish whether or not the precipitation is freezing. By definition, frozen rain or drizzle causes glazed frost by freezing on coming into contact with solid objects. Solid precipitation can occur in the form of diamond dust, snow grains, isolated star-like snow crystals, ice pellets and hail, full descriptions of which are given in WMO (~~1975~~2017).

The precipitation character (intermittent, continuous, showery) and type (rain, drizzle, snow, hail) affect the definition of scales of *precipitation intensity*. Several combined Commission for Instruments and Methods of Observation/Commission for Basic Systems expert team meetings have developed tables to obtain a more universal relation between the qualitative and subjective interpretation by an observer and the measured quantities obtained by a present-weather system. For an example of these tables and other relations, see the ~~annex~~Annex .

#### 14.2.1.2  Instruments and measuring devices: precipitation type

One major area of instrumentation involves the identification of the type of precipitation. Systems which are currently under evaluation, or in operational use, generally involve optical methods or radar (van der Meulen, 2003). Field tests (WMO, 1998) have shown that all of these systems are

capable of detecting major precipitation types – except for the very lightest snow or drizzle – in over 90 % of occurrences compared to a trained observer. The percentage of detection of very lightslight precipitation is usually much lower.[2] Sophisticated algorithms are required to differentiate between several of the precipitation types. For example, wet or melting snow is difficult to distinguish from rain. Sensors detecting precipitation type are listed below. The information of the sensor reporting precipitation type is often post-processed to optimise the results (see for example WMO, 2002 and 2010; and Bloemink, 2004). Currently, sensors reporting precipitation type do not provide information on the quality or uncertainty of the report. Where there are several possible outputs they should all be provided in the form of a probability distribution as this information would be very valuable particularly during post-processing. Sensors detecting precipitation type are listed below. Results of field evaluations of several of these sensors are reported in for example De Haij 2007 and WMO (2008, 2010 and 2016).

**Forward-scatter/backscatter present weather sensor**

A variety of scatter sensors are used to report present weather, in particular precipitation type. In general, scatter of a light source by the precipitation particles is observed under a fixed angle. This gives information on the size of the particles. Additional measurements (such as forward-/backscatter ratio, water content of the particles, fall speed, temperature) help determine the nature of the particles. For example, large particles with small water content will be classified as snow. Some sensors report unidentified precipitation when the precipitation type cannot be properly determined by the system. This mainly occurs at low precipitation intensities and during the start and cessation of precipitation events. Apart from precipitation type, these sensors may (depending on the sensor type) also provide precipitation intensity, precipitation duration (thus able to indicate intermittent precipitation) and visibility.

These sensors are widely in use and generally give acceptable results for common precipitation types (rain, snow), with 70 % – 90 % detection rates (WMO, 1994 and 1998, and Wauben, 2002), depending on the exact test set up and the specific instrument. Other precipitation types are not so well observed, particularly mixed precipitation (rain and snow) and hail. Thresholds for lightslight precipitation may vary.

**Optical disdrometer**

Optical disdrometers are also used to determine precipitation type. These instruments use the extinction of a horizontal (infrared) light sheet to detect hydrometeors. When a particle falls through the light sheet, the receiver intensity is reduced. The amplitude of this reduction correlates with the particle size, and the duration correlates with the particle fall speed. The type of precipitation is determined by comparing the particle fall speed distribution of a series of detected particles against known relationships for different types of liquid, mixed and solid precipitation.

These sensors also generally give acceptable results for common precipitation types. Detection rates compared to human observers are similar to those found for scatter sensors (WMO, 2005a, 2010). Again, mixed precipitation types and hail are difficult to detect.

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[2] The threshold for the detection of rain intensity is 0.02 mm h$^{-1}$ (see PartVolume I, Chapter 1, Annex 1.EA).

A new measurement technique related to disdrometers are the so-called 2D and 3D video disdrometers that also capture projected images of the hydrometeors. These instruments are currently under development or used for research purposes. Examples are the 2D video disdrometer (Schönhuber et al., 2007), the Video Precipitation Sensor (Liu et al., 2014) and the Multi-Angle Snowflake Camera (Praz et al., 2017).

**Doppler radar**

Specific Doppler radars can also be used to determine precipitation type. The (vertically) emitted beam from the radar is backscattered by the falling hydrometeors. From the Doppler shift of the backscattered signal, the particle fall speeds can be determined. Near the ground, these are terminal fall velocities and correspond with the particle sizes. Some instruments have a measuring volume above the sensor; others determine the fall speeds at different altitudes above the sensor to determine precipitation type. Additional measurements (for example, surface temperature) are also used.

Different types of Doppler radar are available for detection of precipitation type. They tend to be insensitive to small particles, like all radar-based detection techniques. Some types show similar results compared with forward-scatter/backscatter sensors and disdrometers, that is, they produce decent results for rain and for snow, but not for mixtures. Hail is not observed.

**Impact detector**

This type of sensor consists of a piezoelectric material which is capable of detecting the impact of the individual hydrometeors. The difference between the impact of hail and rain differs sufficiently to distinguish these two precipitation types. Other precipitation types are not reported. (WMO, 2005b).

Since only rain and hail can be reported, this sensor is not a fully operational present-weather sensor. The hail detection part may, however, be helpful to some users, since this is generally a weak point of other present weather sensors.

**Acoustic detector**

The acoustic detector senses the sound of the falling hydrometeors. This is related to the precipitation type. The sensor was developed to supplement a forward-scatter/backscatter PW sensor, in particular to improve the detection of hail and ice pellets.

Initial results of the sensor were promising (Wade, 2003; Loeffler-Mang, 2009).

**Other methods**

Cameras can also be used to monitor precipitation type. An observer/operator can then monitor the various cameras from a central facility. A proper background needs to be selected in order to observe the precipitation. Since this type of measurement requires an observer/operator, it is not an automatic measurement of present/past weather.

A sensor specifically designed to detect freezing rain or glaze is in operational use (Starr and van Cauwenberghe, 1991). It senses the amount of ice accumulation on a probe. The probe vibrates at a frequency that is proportional to the mass of the probe. When ice freezes on the probe, its mass changes and the vibration frequency decreases. A heater is built into the sensor to de-ice the probe when required. The sensor has also been found effective for identifying wet snow.

A sensor that uses the differences in scintillation patterns when particles pass through a coherent light beam is able to differentiate between rain and snow (NOAA, 1998). Icing detectors may be used to identify freezing precipitation. Various methods exist. For instance, the weight of ice on a pole can be measured. Another method uses a probe that vibrates ultrasonically and the frequency of this probe changes when ice is formed on it. An extensive test has recently been performed (Fikke et al., 2007). Results from PW sensors improve by including data from icing detectors, particularly freezing rain (Sheppard and Joe, 2000). Automated Weather Observing Systems (AWOSs) use this technique.

Hail and other precipitation type products can also be obtained from weather radar measurements (see Volume III, Chapter 7).

### 14.2.1.3  Instruments and measuring devices: precipitation intensity and character

Present weather reports include an indication for the intensity of precipitation and thus of the precipitation character (that is, showers, intermittent precipitation or continuous precipitation). In many cases, these parameters are measured by the same sensor that determines the precipitation type. But it is also possible to employ a different sensor for this purpose. Measuring intensity also allows for the determination of intermittent precipitation (for example, snow showers). A laboratory and field intercomparison for precipitation intensity measurements has recently been completed (WMO, 2006*a*, 2009). This intercomparison included many different instruments using a variety of measurement techniques for collecting precipitation. Automatic measurement methods to provide an indication of precipitation intensity are listed below.

**Forward-scatter/backscatter present weather sensor**

The sensor is described in section 14.2.1.2. By combining the particle size distribution, number of particles and precipitation type, the intensity of the precipitation is calculated. The precipitation intensity determined in this manner is usually less accurate than using conventional methods (for example, weighing raingauges, tipping-bucket raingauges). Calibration of the precipitation intensity is also a problem. For a coarse indication of precipitation intensity (light slight, heavy, etc.), this method is usable. Manufacturers are working on refining the precipitation intensity output.

**Optical disdrometer**

This sensor type is also described in section 14.2.1.2. By combining the particle size distribution, number of particles and precipitation type, the intensity of the precipitation is calculated. Work is being done to refine the precipitation intensity output (see, for example, WMO, 2006*b*).

**Doppler radar**

The sensor is described in section 14.2.1.2. By combining the particle size distribution, number of particles and precipitation type, the intensity of the precipitation is calculated. Precipitation intensity results have shown decent correlations ($\rho = 0.9$) with conventional raingauges when 30 min intervals are considered (see Peters et al., 2002).

**Raingauge**

There are many different types of "conventional" raingauges. These are based on several different measurement methods and described in Part Volume I, Chapter 6. They are generally designed to measure precipitation amount, although some (smaller) instruments are also specifically designed to give (an indication of) precipitation intensity. Those raingauges designed for precipitation

amount tend to be less accurate in reporting precipitation intensity. However, an indication of precipitation intensity, which is required for the present weather reporting, is generally satisfactory. Also, many manufacturers are improving these instruments with respect to the precipitation intensity (WMO, 2006*a*, 2009).

### 14.2.1.4  *Instruments and measuring devices: multi-sensor approach*

To determine present weather characteristics and quantities of precipitation, observing systems use a variety of sensors in combination with algorithms. This multi-sensor approach creates a constraint on the techniques involved. Typical observations also involved are the measurement of precipitation, visibility, air temperature, dewpoint and cloud base. The algorithms are characterized by filtering (for example, liquid precipitation only if the air temperature is above 6 °C). Combining numerous sensors to determine present weather is also used in road-weather systems (see also section 14.3).

### 14.2.2    Atmospheric obscurity and suspensoids

### 14.2.2.1  *Objects of observation*

In reports taking into account the atmospheric conditions during the last hour, haze should be distinguished from mist or water fog. With haze, the air is relatively dry, whereas with mist or water fog, there is usually evidence of high humidity in the form of water droplets or rime on grass, leaves, etc. If the station is equipped with measuring instruments, it is fairly safe to assume that the obscurity is haze if the relative humidity is less than a certain percentage, for example 80 %, and if the visibility is within certain limit values, for example, greater than 1 km in the horizontal, and greater than 2 km in the vertical. Mist is to be reported at high humidity values and at a visibility of 1 km or more. In synoptic reporting, fog is regarded as applying to water or ice fogs, generally reducing the horizontal visibility at the Earth's surface to less than 1 km. Wherever the term "fog" occurs in present weather and past weather codes, it should be read in this sense. In climatological summaries, however, all occasions of visibility of less than 1 km are regarded as fog.

Rime deposit is caused by the solidification into ice of water droplets in fog on coming into contact with solid objects at a temperature below freezing point. The present and past weather codes do not distinguish between different types of rime.

Drifting or blowing snow is snow blown off the ground into the air after it has already fallen. In the present weather code, drifting and blowing snow are distinguished separately, the former referring to snow not raised above the observer's eye level.

Other meteorological phenomena to be identified include widespread dust in suspension in the air, dust or sand raised by wind, a duststorm and sandstorm caused by turbulent winds raising large quantities of dust or sand into the air and reducing visibility severely, dust whirls or sand whirls and, occasionally, funnel clouds.

WMO (19752017) should be at the observer's disposal as an auxiliary means.

### 14.2.2.2  *Instruments and measuring devices for obscurity and suspensoid characteristics*

A possible approach for the identification of obscurity and suspensoid characteristics is the complex processing of measured values which can act as predictors. This approach requires researching the meteorological quantities that accompany the formation, intensification and

disappearance of the phenomenon, as well as determining the limiting conditions. The problem of identifying fog, mist, haze, snowstorms and duststorms is reported in Goskomgidromet (1984) and WMO (1985). The meteorological visual range serves as the most important indicating element. Of the remaining variables, wind velocity, humidity, temperature and dewpoint have proved to be important identifying criteria.

Instruments measuring visibility can be used to determine the meteorological visual range, as described in Part Volume I, Chapter 9, particularly section 9.3. Note that for the determination of fog, mist and haze, however, the range of these instruments can be limited to a few kilometres. Three types of visibility instruments used in the determination of fog, haze and mist are described below.

**Transmissometer**

Transmissometers measure the extinction of a light source over a known distance. Usually, the light of a flash lamp is detected at a distance of between 10 and 200 m. The visibility is calculated from the extinction of this light. In order to increase the range of detection, two detectors at different distances can be used (a so-called double-baseline transmissometer). Transmissometers are well suited to measure visibility, and are widely in use, particularly at airports. For larger visibilities, the uncertainty in the measurement increases with an increase in visibility (for further details, see Part Volume I, Chapter 9, 9.3). They are relatively expensive to install and to maintain, as they require regular cleaning. Some transmissometers are capable of maintaining their operational accuracy significantly longer due to automatic calibration and automatic compensation of contamination effects.

**Forward-scatter sensor**

This sensor is described in section 14.2.1.2. Apart from precipitation type, visibility can also be measured using this instrument. (see Volume I, Chapter 9, 9.3). The amount of scatter is related to the optical extinction. This is determined empirically in the calibration process by comparing the output with a transmissometer. Forward-scatter sensors are also well suited for measuring visibility and are being used increasingly. Compared to the transmissometer, the forward-scatter sensor can be generally used for a larger visibility range. One drawback is that its calibration is not trivial and needs attention. The instrument is relatively inexpensive to install and to maintain, as it does not require cleaning as often as transmissometers. Certain sensors can further extend the cleaning interval by automatic compensation of the optical impact of contamination.

**Lidar**

A relatively small lidar system can also be used to determine the visibility used in the determination of fog. A diode laser emits light pulses, and the light reflected back by the fog/haze particles (if present) is measured. The visibility is determined from the intensity of the reflected light and its time-of-flight. The visibility range measured by a lidar is limited, but for the determination of fog and haze and similar phenomena, a large visibility range is not required.

## 14.2.3    Other weather events

### 14.2.3.1  *Objects of observation*

One event of critical importance in the protection of life and property is the recognition and observation of funnel clouds. spouts (landspout, cold air funnel, tornado, or waterspout, see WMO, 2017).

*Funnel cloud (tornado or waterspout)*:*Spout*: A phenomenon consisting of an often violent whirlwind, revealed by the presence of a cloud column or inverted cloud cone (funnel cloud), protruding from the base of a cumulonimbus. The or cumulus cloud may extend alland of a "bush" composed of water droplets raised from the way down to the Earth's surface, but not necessarily reaching the ground, in which case water, of the sea or of dust, sand or litter may be raised, producing a "bush" around from the tip of the funnelground. The diameter can vary from a few metres to some hundreds of metres. A funnel cloud is considered well developed if the violent rotating column of air touches the ground or water surface. A well-developed funnel cloud is considered a tornado when over ground, and a waterspout when over water. The most violent tornadoes can have associated wind speeds of up to 150 m s$^{-1}$.

*Dust/sand whirls (dust devils)*: A rapidly rotating column of air usually over dry and dusty or sandy ground which carries dust and other light material picked up from the ground.Dust whirl or sand whirl (dust devil): An ensemble of particles of dust or sand, sometimes accompanied by small litter, raised from the ground in the form of a whirling column of varying height with a small diameter and an approximately vertical axis. Dust or sand whirls are a few metres in diameter. Normally, in the vertical they extend no higher than 60 to 90 m (dust devils). Well-developed dust/sand whirls in very hot desert regions may reach 600 m.

*Squall*: A strong wind that rises suddenly, lasts for a few minutes, then passes away. Squalls are frequently associated with the passage of cold fronts. In such circumstances, they occur in a line and are typically accompanied by a sharp fall in temperature, veering wind (northern hemisphere) or backing wind (southern hemisphere), a rise in relative humidity, and a roll-shaped cloud with a horizontal axis (line squall).

The definition of a thunderstorm (see WMO, 1992) is an example of deriving the description exclusively from the perception of human observers. The event should be considered as a thunderstorm when thunder is heard (even if lightning is not observed).

### 14.2.3.2 Instruments and measuring devices

The presence of funnel clouds, or tornadoes, can often be determined with the use of weather radar (see Part IIVolume III, Chapter 7). Modern Doppler weather radars have become quite effective in the recognition of mesocyclones, thus providing more detailed and advanced information about this severe weather phenomenon than visual observation alone.

Squalls can be determined from the discrete succession of measured values of wind velocity. If the output of a wind velocity measuring device is combined with that of a wind direction sensor, a thermometer or a humidity sensor, the identification of a line squall seems to be possible.

Thunderstorms are mainly detected through the use of lightning counters. On the basis of the instructions provided to observers and issued by different Services, a certain number of lightning strokes per interval of time must be selected which can be used in combination with precipitation rates or wind speeds to define slight, moderate and heavy thunderstorms (see Part IIVolume III, Chapter 6).

### 14.2.4 State of the sky

### 14.2.4.1 Objects of observation

The specifications of the state of the sky are used to describe the progressive changes that have occurred in the sky during a given time. Changes in the total amount of clouds, in the height of the cloud base and in the type of cloud are to be considered likewise.

### 14.2.4.2  *Instruments and measuring devices*

Cloud amount characteristics (total cloud cover in oktas, height of cloud base, and total cloud cover in various cloud layers) can be approximated from the variation of cloud-base height measured by a cloud-base optical measuring system by the application of statistical methods (see also PartVolume I, Chapter 15). Obviously, this is limited to cloud layers within the vertical range of the cloud-base measuring system (Persin, 1987; US NOAA, 1988; ICEAWS, 1999).

### 14.3      OBSERVATION OF STATE OF THE GROUND

### 14.3.1      Objects of observation

State of the ground refers to the condition of the surface resulting from recent weather events in terms of amount of moisture or a description of solid, aqueous or non-aqueous particles covering the natural surface. Observations of the state of the ground (symbolic letters E and E´) should be made in accordance with the specifications given in WMO (2011).

Reporting state of the ground is also a part of present weather reporting, which, until recently, was carried out solely by human observers. Automatic measurement of state of the ground is still relatively new (for example, see Stacheder et al., 2008) and not widely in use. Some meteorological institutes are working on standardizing the surface(s) to be observed.

### 14.3.2      Instruments and measuring devices

Research has shown that it is possible to discriminate main states of soil by means of reflecting and scattering phenomena (dry, humid, wet, snow-covered, rimed or iced) (Gaumet et al., 1991). Methods in use are briefly described below.

*Scatter sensor*: These sensors have an optical design that uses the reflecting and scattering properties of the surface. Various light sources may be used. For example, flux from a white light source reflected from a reference tile will depend on the state of this surface. Other (road-) sensors analyse reflection of an infrared light source on a road surface. Here the wavelength of the reflected light depends on the state of the surface. Not all these sensors are suited for meteorological purposes, as they may be designed for surfaces other than natural surfaces. Sensors are currently being improved.

*Capacitive sensor*: A new, capacitive sensor is currently being developed and tested. A grid mat with conductive strips is placed on the (natural) surface. It is basically a capacitor with the natural ground as the dielectric. The dielectric constant for dry and wet earth differs considerably. The capacitance thus depends on the humidity of surface and, by measuring the absolute values and phase of the emitted signals at two frequencies, the state of the ground can be determined. The first results of the tests look promising, but this sensor is still under development.

*Combination of sensors*: Particularly for road surfaces, a combination of sensors may be used to determine the surface state. For example, optical detection may determine the surface coverage; a conductivity measurement may determine the presence of chemical substances, surface temperature and ground temperature, and so forth. All these measurements, combined with atmospheric data, can be used in determining road condition. However, state of the ground is defined as the state on the natural surface present; this method thus determines not the exact state of the ground, but a related property.

*Cameras (and observer)*: Cameras are also used to determine state of the ground. They can be pointed at various surfaces and an observer/operator determines the state of the ground. As this method is basically a manual method of observation, it is not analysed here.

## 14.4        OBSERVATION OF SPECIAL PHENOMENA

### 14.4.1        Electrical phenomena

Electrometeors either correspond to discontinuous electrical discharges (lightning, thunder) or occur as more or less continuous phenomena (Saint Elmo's fire, polar aurora). Full descriptions of electrometeors are given in WMO (19752017).

Special records of lightning should include information regarding its type and intensity, the frequency of flashes and the range of azimuth over which discharges are observed; the lapse of time between lightning and the corresponding thunder should be noted. Care should be taken to distinguish between the actual lightning flash and its possible reflection on clouds or haze. Automatic detection systems for lightning location are in operational use in many countries. PartVolume III, Chapter 6, contains more information on this topic.

Exceptional polar aurora should be described in detail. Light filters, where available, may be used as a means of increasing the sensitivity of the observations, and theodolites or clinometers (alidades) may be used to increase the accuracy of the angular measurements.

### 14.4.2        Optical phenomena

A photometeor is a luminous phenomenon produced by the reflection, refraction, diffraction or interference of light from the sun or moon. Photometeors may be observed in more or less clear air (mirage, shimmer, scintillation, green flash, twilight colours), on or inside clouds (halo phenomena, corona, irisation, glory) and on or inside certain hydrometeors or lithometeors (glory, rainbow, fog bow, Bishop's ring, crepuscular rays).

Observers should take careful note of any optical phenomena that occur. A written description should be accompanied by drawings and photographs, if possible. Full descriptions of these phenomena are given in WMO (19752017). Concise instructions for observing the more common phenomena are given in some observers' handbooks, for example, the United Kingdom Meteorological Office (1982).

A theodolite is a very suitable instrument for precise measurements. However, when one is not available, a graduated stick held at arm's length is useful; with the occurrence of a mock sun, the position may be determined by noting its relation to fixed landmarks. The diameter of a corona may be estimated by taking the angular diameter of the sun or moon as approximately half a degree.

## ANNEX. CRITERIA FOR ~~light~~**SLIGHT**, MODERATE AND HEAVY PRECIPITATION INTENSITY[3]

(~~Light~~Slight, moderate and heavy precipitation defined with respect to the type of precipitation and to intensity, $i$)[a]

| TABLE: Table horizontal lines | | |
|---|---|---|
| *Variable* | *Range* | *Intensity* |
| Drizzle | $i < 0.1$ mm h$^{-1}$ | S~~l~~light |
| | $0.1 \leq i < 0.5$ mm h$^{-1}$ | Moderate |
| | $i \geq 0.5$ mm h$^{-1}$ | Heavy |
| Rain (also showers) | $i < 2.5$ mm h$^{-1}$ | S~~l~~light |
| | $2.5 \leq i < 10.0$ mm h$^{-1}$ | Moderate |
| | $10.0 \leq i < 50.0$ mm h$^{-1}$ | Heavy |
| | $i \geq 50.0$ mm h$^{-1}$ | Violent[b] |
| Snow (also showers) | $i < 1.0$ mm h$^{-1}$ (water equivalent) | S~~l~~light |
| | $1.0 \leq i < 5.0$ mm h$^{-1}$ (water equivalent) | Moderate |
| | $i \geq 5.0$ mm h$^{-1}$ (water equivalent) | Heavy |

Notes:

a   Intensity values based on a 3 min measurement period.

b   The term "violent", as it pertains to precipitation rate, is inconsistent with the other categories and is confusing. A term such as "intense" or "extreme" may be more appropriate.

## Criteria for other precipitation types

**Mixed precipitation of rain and snow**

: The same as for snow (since the rain/snow ratio is not subject to any measurement, a simple choice should be made).

Hail: The same as for rain.

Ice pellets and snow pellets: The same as for snow.

Freezing phenomena: The same as for the non-freezing phenomena.

**Guide for approximating the intensity of snow**

~~Light~~Slight: Snowflakes small and sparse; in the absence of other obscuring phenomena, snow at this intensity generally reduces visibility, but to no less than 1 000 m.

Moderate: Larger, more numerous flakes generally reducing visibility to between 400 and 1 000 m.

Heavy: Numerous flakes of all sizes generally reducing visibility to below 400 m.

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[3] Recommended by the WMO Expert Meeting on Automation of Visual and Subjective Observations (Trappes/Paris, France, 14–16 May 1997) and the Working Group on Surface Measurements (Geneva, 27–31 August 2001).

**Showers or intermittent precipitation**

Automated systems should report showers or intermittent precipitation. Intermittent can be defined as no precipitation within 10 m̶i̶n̶minutes of two consecutive precipitation events, i.e. if there is a period of 10 m̶i̶n̶minutes of no precipitation in a running 10 min average of precipitation within the last hour, it should be reported as intermittent.

**Representativeness of present weather events**

A present weather event may be well defined by a 3 min observing period. The highest running 3 min average in the 10 min period should be reported for present weather.

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SECTION: Chapter_book
Chapter title in running head: CHAPTER 14. OBSERVATION OF PRESENT AND …
Chapter_ID: 8_I_14_en
Part title in running head: PART I. MEASUREMENT OF METEOROLOGICAL VARI…

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