meteoblue weather variable definitions

Explanations of forecast and history variables

0 Introduction

This document gives a detailed overview over all weather variables.

1 Cloud variables

1.1 Cloud Cover

Cloud cover is expressed in percent (%). Zero means that there is no visible cloud in the sky. Fifty percent is equivalent to half of the sky being covered with clouds. Hundred percent cloud cover means no clear sky is visible. Cloud cover can be divided into:

- Low cloud cover: 0- 4 km/ below an altitude of 640hPa (5km at equator)
- Mid cloud cover: 4- 8km/ between an altitude of 640 and 350hPa (10km at equator)
- High cloud cover: 8- 15km/ between an altitude of 350 and 150 hPa (18km at equator)
  Note that high clouds are thin ice clouds which, even when reaching 100%, might be almost invisible in some cases

1.2 Cloud Ice

Total atmospheric column frozen water content of all clouds, excluding precipitation. It's unit is gram (g).

1.3 Cloud Water

Total atmospheric column liquid water content of all clouds, excluding precipitation. It's unit is gram (g).

2 Humidity

2.1 Dew Point Temperature

The dew point is the point at which dew starts to form on solid surfaces (that is for example the drops on grass that appear early in the morning). By definition it is the air temperature (°C) at which a specific volume of air (that has a constant pressure) condenses water vapour into liquid water at the same rate as it evaporates. This also means that the vapour pressure is equal to the saturation vapour pressure. If the relative humidity is 100%, the dew point temperature is the same as the air temperature. Thus the air is saturated. If the temperature decreases, but the amount of water vapour stays constant, water will start to condensate. This condensed water is called dew as soon as it forms on a solid surface. It is expressed in degrees Celsius (°C) as well as in degrees Fahrenheit (°F).

2.2 Evapotranspiration

2.2.1 Potential Evapotranspiration

Potential evapotranspiration is a theoretical value and explains how much water would evaporate from a water surface. It is often not realistic, for example, the value of potential evapotranspiration in the Sahara is very large, but actually there is no water to evaporate. Potential evapotranspiration is expressed in millimetre (mm).

2.2.2 Total Evapotranspiration

Sum of evaporation (soils, lakes, seas) and transpiration (plants). Total evapotranspiration is described in millimetre (mm).

2.3 Relative Humidity

Relative humidity indicates how saturated the air is with moisture (expressed in percent (%)). If relative humidity approaches 100%, then clouds/fog begin to form. Note that relative humidity is strongly dependent on air temperature, keeping the amount of water equal, relative humidity decreases with increasing temperature.

2.4 Leaf Wetness Index

This index indicates if leaves are wet (1) due to precipitation, dew or dry (0). Hourly values are 0 or 1, the daily values might be 0.5, meaning that 12 hours had wet leaves and 12 hours had dry leaves. The leaf wetness time is the time of hours when leaf temperature equals dew temperature or when it is raining (the leaf is assumed to be wet).

2.5 Visibility

Visibility is the distance (in metres (m)) at which an object can be clearly seen. Note that visibility is extremely difficult to forecast especially if visibility is reduced to less than 3000 m.

3 Precipitation

3.1 Precipitation

Precipitation is the deposition of water to the Earth's surface, in form of rain, snow, ice or hail. All precipitation quantities are expressed in millimetres (mm) of liquid water. One millimetre of rain corresponds to one litre of water per square meter and to approximately 7 millimetres of snow height. Note that precipitation amounts are very difficult to forecast.

3.2 Convective precipitation

Convective precipitation is caused by convective weather (e.g. thunderstorms). Therefore, air rises into the atmosphere, because of extreme heat. When air rises to high atmospheric levels, it cools down and consequently, vapour condenses into precipitation.

3.3 Precipitation Probability

Precipitation probability is the likelihood with which a precipitation amount of more than 0.2 mm of rain occurs within the time window of the last one, three or 24 hours, respectively. It is based on different forecast models and called ensemble forecasts. Therefore, precipitation probability has less spatial resolution and is representative for a larger area than precipitation quantity. It is expressed in percent (%).

Probabilities are very difficult to understand:

A perfect forecast of probability would mean that there are 100 forecasts and they all predict a precipitation probability of 30%. Then, in 30 cases it would rain and in 70 cases it would not rain.

Thus, a single forecast for tomorrow could show a precipitation probability of 70% together with a precipitation amount of 0mm or a precipitation probability of 30% together with 10mm of rain. This would all be correct.

Another example: Some people might think it is a good idea to show rain as soon as probability exceeds 50%. However this would be wrong, because on 100 days for which 50% probability is forecasted, it will only rain on 50 days.

3.4 Precipitation Spread

Precipitation spread indicates the uncertainty in the forecast as computed by the ensemble prediction. It is defined as one standard deviation of the computed variation. It´s unit is millimetre (mm).

3.5 Precipitation Type/ Snow Fraction

Precipitation can be divided into several types: meteoblue displays 2 precipitation types- rain and snow. Rain is expressed as 0 and snow as 1.

3.6 rainSPOT

The rainSPOT is a regional overview of precipitation. It shows precipitation in the surrounding of the selected location for the time interval preceding the indicated time. It has 49 values corresponding to a 7 by 7 grid. The actual forecast location for which all the other variables are valid is located in the centre of the rainSPOT. The 49 values of the rainSPOT in the datafeed are ordered from South-West to North-East thus following the mathematical definition of a coordinate system, with origin in the South-West (lower left) corner. Figure 3.1 illustrates how to insert the 49 values (1 to 49) into the rainSPOT (7 by 7 grid).

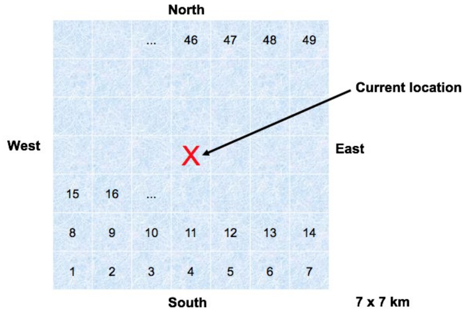

Figure 3.1: rainSPOT

3.7 Snow

Snow is a special form of precipitation in the form of crystalline water ice, consisting of a multitude of snowflakes that fall from the clouds. As soon as snow settles on the surface, it is rapidly compressed by further snowflakes.

3.7.1 Snow Cover

It is the amount of accumulated snow (in mm) on the ground. This is a crude estimate and cannot be used to e.g. indicate how much snow is available in a particular ski resort.

3.7.2 Snowfall Amount

Snow fall accumulates on the surface and can reach deposits of up to several meters in certain areas. Snowfall amount expresses the height of snow cover in centimetres (cm). As a rule of thumb, 10cm of fresh snowfall corresponds to 1cm of water.

4 Predicability

Predictability is the estimated certainty of our forecast. It considers uncertainties in pressure, precipitation, temperature, clouds, wind as well as climate inconsistencies. Predictability is expressed as percentage from 0% (worst) to 100% (perfect).
Predictability is also subdivided into 5 classes: very low, low, medium, high and very high.

5 Pressure

5.1 Sea Level Pressure

It is the atmospheric pressure at sea level. For locations which are not at sea level, the pressure is corrected to represent pressure at sea level. Sea level pressure is expressed in hectopascal (hPa).

6 Radiation

6.1 Air Density

Air density decreases rapidly with altitude and also with increasing temperature and humidity.Unit of measurement is kilogram per cubic metre (kg/m^3).

6.2 Boundary Layer Height

Boundary layer height is expressed in meters (m). It is the height up to which air and pollutants (originating from the surface) are mixed up to. If the boundary layer height remains low during the entire day and over several days, than air quality can significantly decrease. A typically daily course is seen in the boundary layer height with maximum values in the afternoon and minimal values during the night.

6.2.1 Planetary Boundary Layer Height (PBL- Height)

Basically, it is the same than boundary layer height but within the atmosphere (between 1 km and the Earth´s surface). Also expressed in meters (m).

6.3 Heat Flux

6.3.1 Latent Heat Flux

Latent heat flux is the same than evapotranspiration- the sum of evaporation (soils, lakes, seas) and transpiration (plants). But it is expressed in watt per square meter (W/m^2).

6.3.2 Sensible Heat Flux

Energy flux from the surface that is warming the air temperature. Sensible heat flux is expressed in watt per square meter (W/m^2).

6.4 Solar Radiation

6.4.1 Extraterrestrial Solar Radiation

Maximum radiation intensity reaching the top of the Earth atmosphere is the extraterrestrial solar constant of 1368 W/m^2 (1321 to 1413 W/m^2 depending on distance of the Earth to the sun). It is dynamically modelled depending on the sun angle and expressed in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.2 DIF (Diffuse Horizontal Irradiance)

Complementary to DIR (Direct Horizontal Irradiance) there is also Diffuse Horizontal Irradiance, which is defined as the scattered radiation or skylight. The diffuse share is very much depending on the sun height and on the clearness of the atmosphere. It is modelled according to Reindl and is expressed in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.3 DIR (Direct Horizontal Irradiance)

The Direct Horizontal Irradiance is the directional share of the shortwave radiation(GHI). Direct radiation is coming from sun direction and therefore is also called circumsolar radiation. In cloudy sky condition, the direct radiation share is equal to 0. It is measured in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.4 DNI (Direct Normal Irradiance)

Direct Normal Irradiance is the direct irradiance on surfaces perpendicular to the sun rays (tracking the sun). Of interest mainly for solar thermal and concentrated photovoltaic power generation. It is measured in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.5 GHI (Shortwave Radiation)

Solar radiation is defined as the amount of total short-wave radiation energy reaching the horizontal Earth surface. Technically, it is also referred to as GHI (Global Horizontal Irradiance). The GHI can be split up into 3 components: diffuse, direct and reflected radiation. All radiation variables are measured in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.6 GNI (Global Normal Irradiance)

Global Normal Irradiance is the global irradiation on surfaces perpendicular to the sun rays (tracking the sun) and is expressed in watt per square meter (W/m^2) or joules per square centimetre ($J/J/cm^2$).

6.4.7 GTI (Global Titled Irradiation)

Global Tilted Irradiation is the global irradiance on a defined surface inclination, which is usually a PV module. All PV system simulations are based on the irradiation on the module plane. It is measured in watt per square meter (W/m^2) or joules per square centimetre (J/cm^2).

6.4.8 IAM (Incidence Angle Modifier)

The glass surface of a PV system reflects the incoming radiation depending on the inclination angle. The Incidence Angle Modifier describes the share of radiation that is available for power generation. It has no unit and the value is always between 0 and 1.

6.4.9 Module Temperature

The Module Temperature describes the temperature of the solar cell. It is influenced by the outside temperature, the irradiation and the wind speed and has significant effect on the Performance ratio (PR). It's unit is °C.

6.4.10 Performance Ratio (PR)

The performance ratio describes the efficiency of a power plant and varies significantly within different weather conditions. It is depending on surface reflectance, module temperature, spectral sensitivity and snow coverage and is expressed in percent (%).

6.4.11 PV Power

Photovoltaic power generation is the generated electricity power output of a specific PV system. The system efficiency to convert GTI to power is modelled depending on surface reflectance, module temperature, spectral sensitivity and snow coverage. It is expressed in kilowatt (kW) or kilowatt per hour (kW/h).

6.5 Snow Cover

The snow cover describes the height of snow on a horizontal surface. Based on the snow height the PV power output is adjusted. It is expressed in millimetres (mm).

6.6 Sunshine Time

Sunshine time is the amount of minutes with expected sunshine. It is indicated as minutes or hours respectively.

6.7 UV- Index

The ultraviolet index (UV index) is an international standard measurement of the strengths of the ultraviolet radiation from the sun. The purpose is to help people to effectively protect themselves from UV light. The UV index value always refers to the highest possible value that can be achieved at midday. It is expressed in index numbers from 1 to 16. Note that values above 11 should be shown as 11+. This is illustrated in figure 6.1.

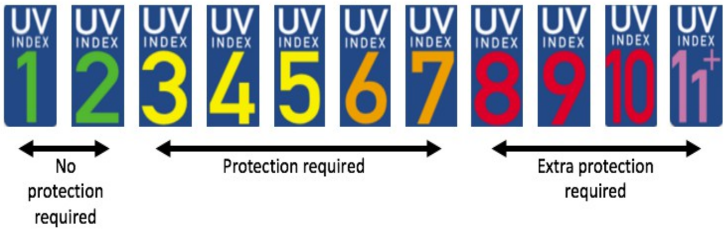

Figure 6.1: UV index table

7 Sea variables

7.1 (Spectral) Characterization

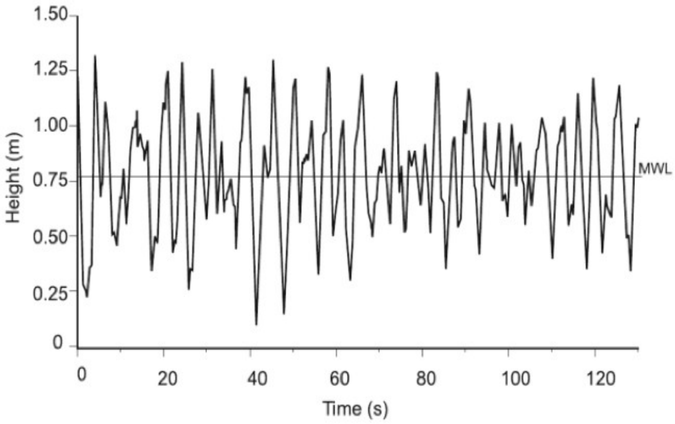

Figure 7.1: Measurement of wave heights over time

Figure 7.1 shows measurements of wave heights over time. This can be mathematically transformed into an energy spectrum (Figure 7.2), showing the amount of energy at a given wave period/frequency.

Figure 1.2 shows the spectrum for a fully aroused (old) wind sea. The energy of the waves increases exponentially with wind speed. The spectrum has a peak, where most energy is found which corresponds to a certain wave period (or frequency). This we call the peak or primary wave period Note that high energy waves produced with strong winds have lower frequencies (or longer periods).

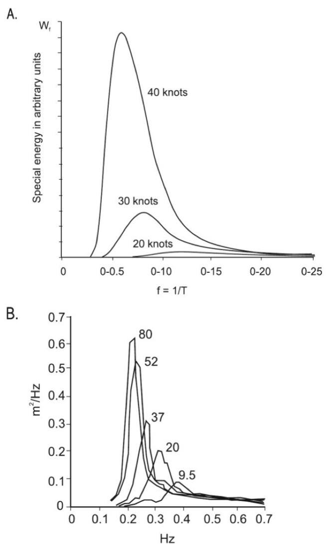

Figure 7.2: Spectrum for a fully aroused wind sea

The spectrum for figure 7.2 A) is the results of steady winds blowing for a long time over large distances. It is called an old sea or fully aroused sea. The old sea develops however from a young sea when wind starts blowing equally over different distances. This growth is shown in Figure 1.2 B), where the numbers show distances of equal wind speed. At the beginning or with wind blowing close to the shore (curve labels with 9.5) the spectra is very broad, meaning there are many waves with different periods but none have a lot of energy (a horrible situation if you want to go surfing). Over time the spectrum becomes narrower and the remaining waves become more powerful. Also the peak wave period increases (wave frequency decreases) until it reaches equilibrium looking like image 7.2A) (very good surf conditions, with few very large waves).

7.2 Peak/ Primary Waves

7.2.1 Peak/ Primary Wave Direction

The peak wave direction identifies the directional movement of the peak wave swells, the dominant wave system (swell) that is generated elsewhere. For more than one swells, the swell containing the maximum energy is considered. Peak wave direction is the direction where the waves come from. We thus use the same convention as for the wind direction (degrees (°)).

7.2.2 Peak/ Primary Wave Period

The peak wave period identifies either the period (the time between waves) associated with the locally generated wind sea (in cases with strong local winds) or the dominant wave system (swell) that is generated elsewhere. This average time period between 2 peak waves is measured in seconds.

7.3 Sea Surface Temperature (SST)

Mean temperature of the ocean in the upper few meters. Note that water temperatures at the beach might be warmer than indicated by the SST. The SST is indicated in degrees Celsius (°C).

7.4 Significant Wave Height

Average of the largest 33% of the waves over a recording time period. It corresponds with the wave height, a skilled observer would determine when looking at the sea filled with waves of different heights. The significant wave height are average numbers, therefore, some individual waves are much higher. The significant wave height is indicated in meters (m).

7.5 Swell Waves

7.5.1 Significant Height Of Swell Waves

Swell waves are generated far away from your current location and may have travelled very long distances (1000's of km). Swell waves can be very large even though there is no local wind. The significant height of swell waves is the average of the largest 33% of the swell waves over a recording time period. Theses are average numbers, therefore, some individual waves are much higher. The swells are calculated from the wave energies below the separation frequency. The peak wind direction is indicated in degrees (°).

7.5.2 Mean Period Of Swell Waves

Mean period of the swell in seconds. The mean period is critical surf knowledge because it ultimately measures the quality of the upcoming surf session. The following table describes different wave periods.

Table 7.1: Wave Period of Quality Surfing

Wave period (s)	Wave Conditions
1- 5	Local wind swells with bumpy and disordered waves, poor surfing conditions
6- 8	Regional and local wind swells with average surfing conditions, offshore winds might get it better
8- 10	Medium-distance swells, improvement of the local surfing conditions
10- 12	The power of ground swells is taking effect, definitely worth it
+ 13	A long period swell brings high-quality waves, epic surf session ahead

Long-period swells accumulate energy, travel faster, and can easily cope with local winds and currents, resulting in larger surf when it comes to average wave height.

7.6 Wind Waves

7.6.1 Wind Wave Direction

Wind waves are caused by the local wind. Wind wave direction is the direction where the wind wave comes from. We thus use the same convention as for the wind direction (°). Wind waves are only generated if local winds are sufficiently strong.

7.6.2 Wind Wave Height

Average height of the 33% highest waves generated by the local wind over a recording time period. Wind waves are only generated if local winds are sufficiently strong. The wind wave height is indicated in meters (m).

7.6.3 Wind Wave Mean Period

Average wind wave time period (in seconds) is the time between waves of the locally generated wind sea. Wind waves are only generated if local winds are sufficiently strong.

8 Soil variables

8.1 Soil Fraction

8.2 Soil Moisture

Soil moisture is the mean moisture of the uppermost 10 cm of soil. It is indicated as volumetric percentage. Thus indicating which fraction of the entire soil volume is filled with water. Typical values are in the range of 10% to 40%. Note that soil moisture will mainly show larger seasonal variations but not give significant signals on a daily or weekly basis.

8.3 Soil Temperature

Soil temperature is the average temperature of the uppermost 10 cm of soil.

9 Storm Prediction/ Convective Weather variables

9.1 CAPE

Convective available potential energy (CAPE) is the available amount of energy for convection.
The higher the value, the greater the potential for severe weather. It is expressed in joules per kilogram (J/kg). Observed values in thunderstorm environments often may exceed 1000 joules per kilogram (J/kg) and in extreme cases may exceed 5000 J/kg.

- CAPE < 1000J/kg = weak instability
- CAPE > 1000J/kg = moderate instability
- CAPE > 2500J/kg = strong instability

9.2 Lifted Index (LI)

The lifted index is a measure of atmospheric instability. The temperature value of the ground is computed and compared with the actual temperature at a specific pressure height. The difference between both values is the lifted index. The air is stable for positive index numbers and unstable for negative index numbers. The more negative, the more unstable the air is, and the stronger the updrafts are likely to be with any developing thunderstorms. However there are no "magic numbers" or threshold LI values below which severe weather becomes imminent but some people use the following rule of thumb:

- LI 6 or greater = very stable conditions
- LI between 1 and 6 = stable conditions, thunderstorms not likely
- LI between 0 and -2 = slightly unstable, thunderstorms possible with lifting mechanism (e.g. cold front, daytime heating etc.)

- LI between -2 and -6 = unstable, thunderstorms likely, some severe with lifting mechanism
- Li less than -6 = very unstable, severe thunderstorms likely with lifting mechanism

9.3 Helicity

Identifies the potential for helical flow (e.g. flow which follows the pattern of a corkscrew) to evolve. It can be useful to identify thunderstorm types. It is expressed in meters square per second squared (m^2/s^2).
Rule of thumb:

- 0-50 m2s2 = low possibility for storms, thunderstorms and tornadoes
- >100 m2s2 = strong thunderstorms
- 150- 200 m2s2 = tornados likely

Note however that this should not be used as as automated tool to forecast tornadoes, it is rather one factor an experienced meteorologist considers together with many others when issuing tornado warnings.

9.4 Convective Inhibition (CIN)

A measure of the **un**likelihood of thunderstorm development. It represents the amount of energy which an air parcel needs, to reach the level of free convection. Low level air parcel ascent is often inhibited by stable layers near the surface. If natural processes fail to destabilize the lower levels, an input of energy from forced lift (a front, an upper level shortwave, etc.) will be required to move the negatively buoyant air parcels to the point where they will rise freely. Since CIN is proportional to the amount of kinetic energy that a parcel loses to buoyancy while it is colder than the surrounding environment, it contributes to the downward momentum. Convective inhibition is expresses in joules per kilogram (J/kg).

The presence of CIN doesn't preclude thunderstorm development as long as it isn't too high. In fact, a moderate amount of CIN in the morning hours is actually favourable to the development of heavy afternoon thunderstorms in the presence of a large amount of CAPE. High CAPE and low CIN morning environments tend to cloud up very quickly after a small amount of surface heating is introduced. Watch for the CIN to go to zero in the afternoon on high CAPE days. This is warning flag that afternoon convection is likely (at least from the point of view of the model).

Rule of thumb:

- CIN < 50J/kg = weak cup that can e easily broken by surface heating
- CIN between 50 and 200J/kg = moderate cap that can be broken by strong heating/synoptic scale forcing
- CIN > 200J/kg = strong cap impedes thunderstorm development

10 Temperature

10.1 Air Temperature

Air temperature is calculated for 2 meters above the ground at any given location and altitude. Temperature is expressed in degrees Celsius (°C) and degrees Fahrenheit (°F).

10.2 Felt Temperature

Felt temperature is the perceived temperature that people experience. It considers the cooling effect of wind (wind chill) as well as heating effects caused by relative humidity, radiation and low wind speeds. It is expressed in degrees Celsius (°C) and degrees Fahrenheit (°F).

10.3 Skin/ Surface Temperature

Skin or surface temperature is also called radiative temperature and is a measure of the temperature of the surface. It is expressed in degrees Celsius (°C) and degrees Fahrenheit (°F).

10.4 Temperature Spread

Temperature spread indicates the uncertainty in the forecast as computed by the ensemble prediction. It is defined as one standard deviation of the computed variation and is expressed in degrees Celsius (°C) and degrees Fahrenheit (°F).

11 Wind

11.1 Wind Direction

Table 11.1: Wind direction and degrees

Cardinal Direction	Degree Direction
N	348.75 – 11.25 (0/ 360)
NNE	11.25 - 33.75
NE	33.75 - 56.25
ENE	56.25 - 78.75
E	78.75 - 101.25
ESE	101.25 - 123.75
SE	123.75 - 146.25
SSE	146.25 - 168.75
S	168.75 – 191.25
SSW	191.25 - 213.75
SW	213.75 - 236.25
WSW	236.25 - 258.75
W	258.75 – 281.25
WNW	281.25 - 303.75
NW	303.75 - 326.25
NNW	326.25 - 348.75

It is the direction from which the wind blows (e.g. north wind comes from the north and blows to the South corresponding to a direction of 0 degrees). It is expressed in degree (°), 2 characters and 3 characters for 10 or 80 meters above ground. The following table illustrates the correspondence of wind direction to degrees and the wind rose gives an overview over cardinal wind directions:

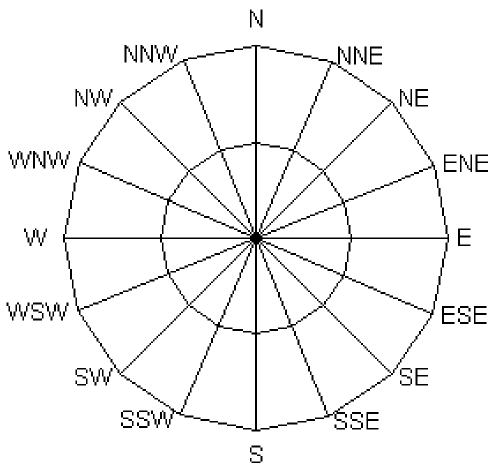

Figure 11.1: Wind rose

Presentations:

- *Arrows:* The arrowhead points to the direction to which the wind blows:
  → West wind- comes from the West and blows to the East
  ← East wind-comes from the East and blows to the West
  ↓ North wind- comes from the North and blows to the South
  ↑ South wind- comes from the South and blows to the North

- *Wind barbs:* The wind barn shows the wind direction along with wind speed. The part of the barb with the attached feather(s) points in the direction from which the wind comes

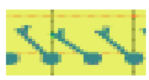

Figure 1: Wind barbs for North-West wind

- *Degrees:*
  0°/ 360°(North): Wind blows from the North to the South (↓)
  90° (East): Wind blows from the East to the West (←)
  180°(South): Wind blows from the South to the North (↑)
  270°(West): Wind blows from the West to the East (→)

- Characters
  - 1 character: North (N), West (W), South (S), East (E) → 90° distance
  - 2 character: N, NW, SW, W, SE, E, NE, E → 45° distance
  - 3 character: N, NNE, NE, ENE, E, ESE, SE, S etc. → 22.5° distance

11.2 Wind Gust

Wind gusts indicate how turbulent the wind is. It is the speed that can be expected for short periods of time, which can be much higher than the wind speed, which is an hourly mean wind speed. This value can vary enormously. Note that you can have a mean wind speed of 10 m/s and gust winds of only 3 m/s. This indicates that the 10 m/s wind is very constant without much variation in speed. If you are not interested in the turbulence information you might slightly modify the gust wind for displaying it to your users by making sure the gust winds are always larger or equal to the mean wind speed, to avoid confusion why the gust should be smaller than the mean wind speed.

Gust wind is expressed in meters per second (m/s), kilometres per hour (km/h), miles per hour (mph), knots (kn) and beaufort (bf) for 10 or 80 meters. As gust wind are turbulent it is not possible to predict a direction of the gusts as it varies randomly.

11.3 Wind Speed

Wind speed is the rate at which air is moving horizontally. meteoblue expresses wind speed in meter per second (m/s), kilometres per hour (km/h), miles per hour (mph), knots (kn) and beaufort (bf). Wind speed is expressed as an hourly mean value. Wind is very turbulent and thus the actual wind speed can be much higher than indicated by the mean wind, but only for short time periods. This short periods of high wind speed are called gusts. Typical gusts speed which can be expected are indicated by the variable gust wind. Unless otherwise marked in the variable name it is valid for 10 m above ground. Windspeed 80m would be valid at 80 m above ground.

11.4 Wind speed spread

Wind speed spread indicates the uncertainty in the forecast as computed by the ensemble prediction. It is defined as one standard deviation of the computed variation. It´s unit is millimetre (mm).