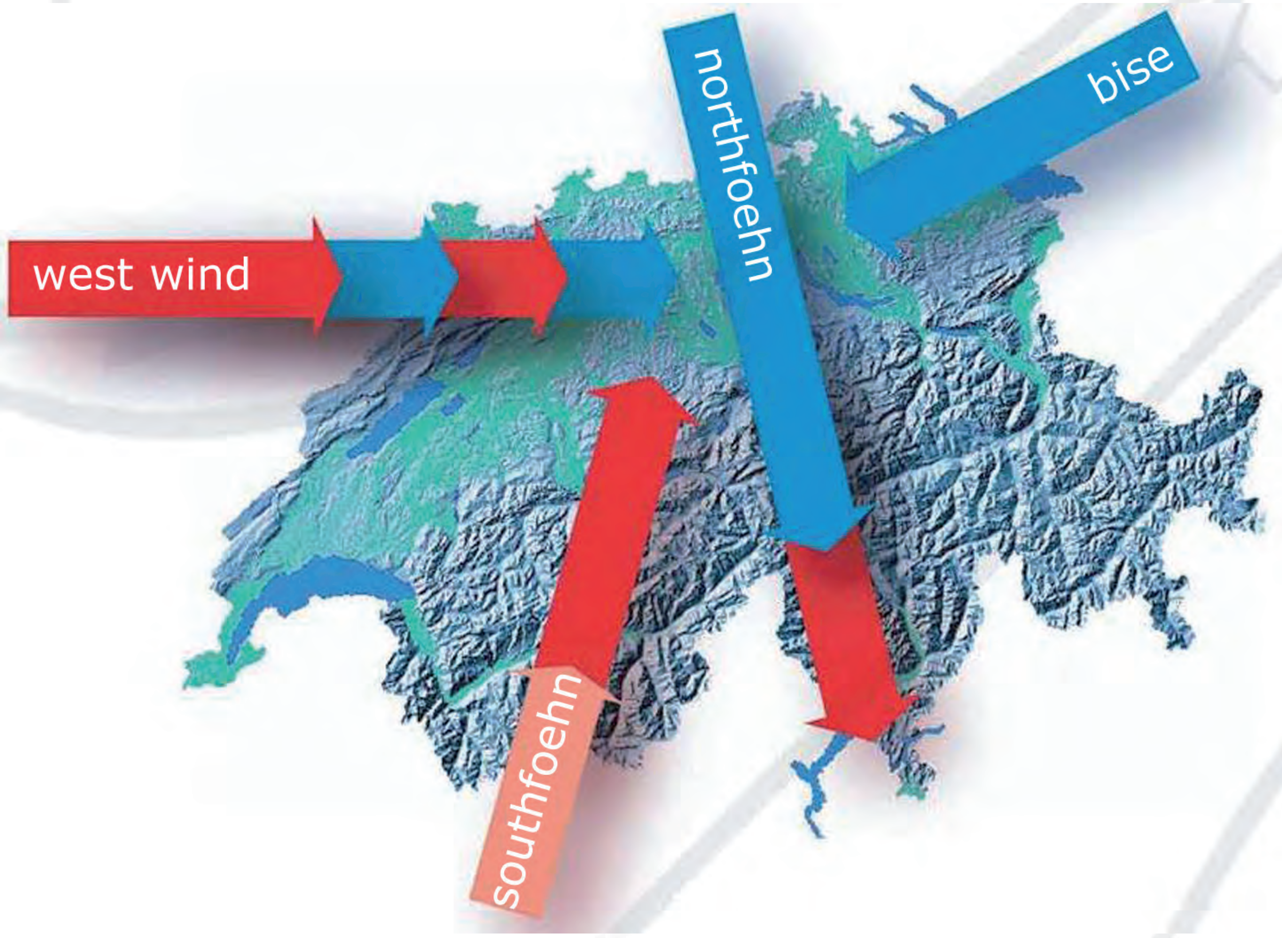
Typical Weather Situations in the Alps



Kantonsschule Enge Zürich
Immersive Geography

by Klaus Burri

1. Clouds and Precipitation

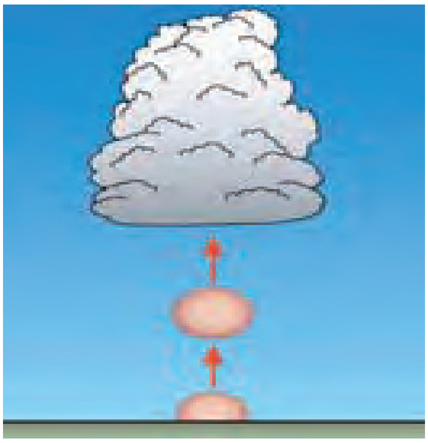
Uplifting air masses cool off, hence can bear less humidity, and hence precipitate [= *ausfällen*] humidity as small water droplets. Being very small at the beginning, they are carried by updraft and thus float through the air. If they are dense enough, we see these little waterdrops as mist [= *Dunst wegen zu hoher Luftfeuchtigkeit*] or clouds.

Still, it does not yet rain, snow or hail. In order to do so, the air masses must be cooled off more: The process of cooling must continue. If not, the clouds will stop evolving and will collapse.

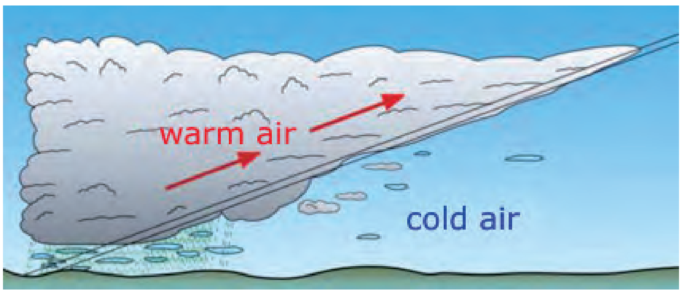
To structure the immense number of various clouds, they are structured by different criteria, such as height, convectivity [= *Konvektivität*], shape, to name only a few. Please read carefully in your geography books: GGCH, pp. 301–303; AGG, p. 156 («Rainfall Patterns»), p. 158 («Types of Rainfall») and pp. 163/64 («Clouds and Fog»).

Reading these passages, you will learn about three types of rainfall, i.e. three possibilities how air masses cool off: convectionally (intense radiation is needed), frontally or cyclonically (two air masses with different temperatures are needed) and finally orographically (mountainous terrain is needed).

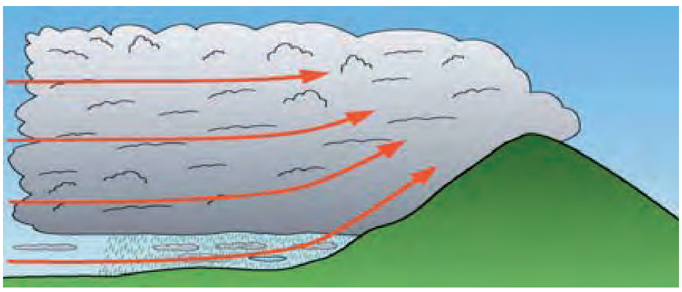
Convectional Type of Precipitation
Heated air rises in warm air bubbles and, therefore, cools down.



Frontal Type of Precipitation
Warm air flows over cold air, ascends and, therefore, cools down.



Orographical Type of Precipitation
Air flows over a mountain range, ascends and, therefore, cools down.



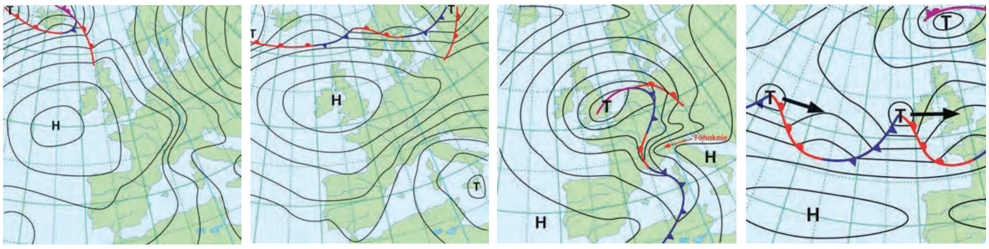
2. Typical Weather Situations in the Alps

Basically, we distinguish between advective and convective weather situations.

Advective weather situations are caused by a macro-scale wind which itself is caused by large pressure systems; e.g. westerly winds are caused by high pressure over the Azores and low pressure over Iceland. In meteorology, the term **advection** is generally applied to a horizontal movement of air over several hundred kilometres (hence macro-scale).

Therefore, in Switzerland we define (for the four points of the compass) four advective weather situations (cf. figure below):

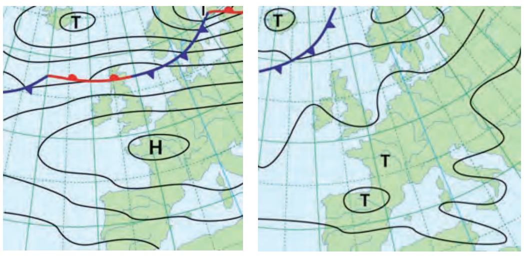
northfoehn, bise, southfoehn, and **west winds.**

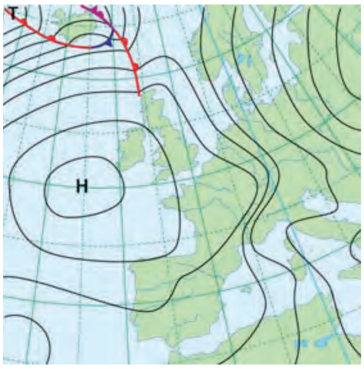


Convective weather situations are not controlled by macro-scale pressure systems, i.e., we must have a relatively flat pressure distribution. Either we are in the middle of a high-pressure cell or far away from all the pressure centres (i.e. in a kind of saddle). In neither case an advective wind blows, hence local differences in temperature will cause small high- and low-pressure zones; and these will cause local winds (cf. AGG, p. 175). In meteorology, the term convection is generally applied to vertical motion in connection with intense radiation and buoyancy [= *hier: Auftrieb*].

Therefore, in Switzerland we define two convective weather situations:

anticyclone and flat pressure distribution.





2.1 Northfoehn Situation

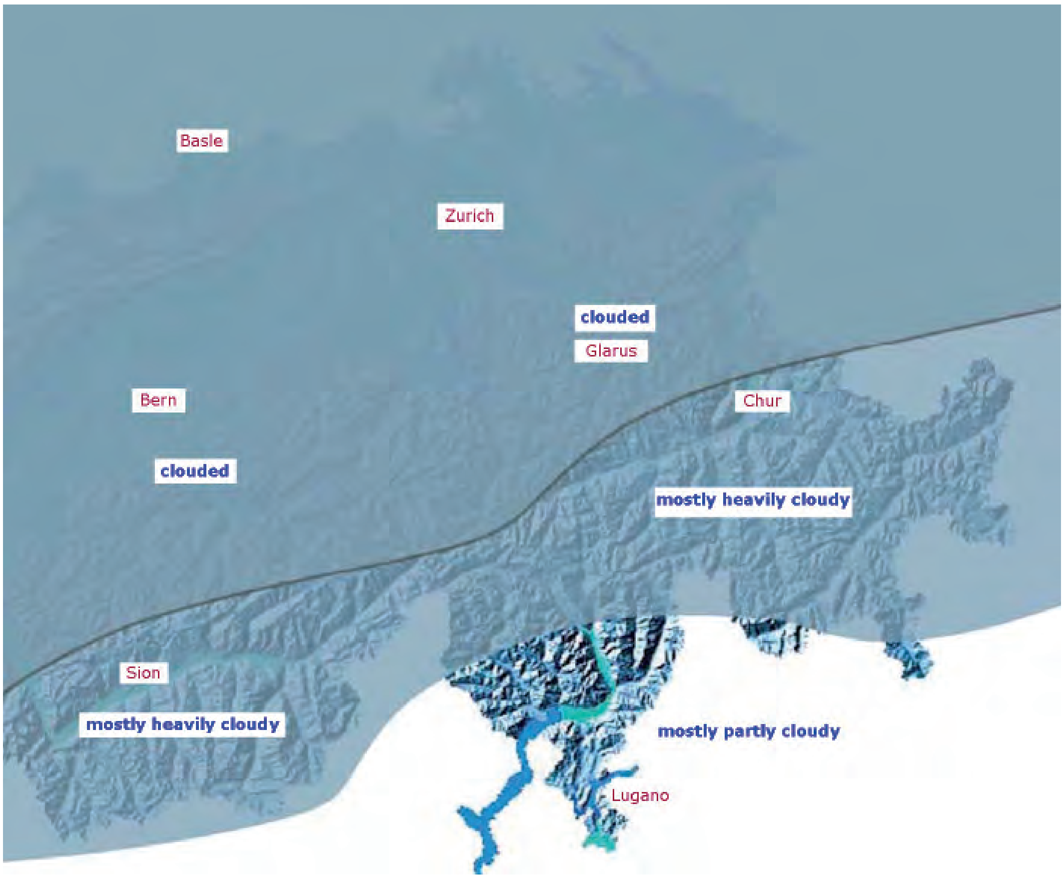
This weather situation is principally the reverse of the southfoehn case. Please also read in GGCH, p. 305: (= *Staulage*).

The centre of the high-pressure area is situated in the West of Switzerland. During this distribution of pressure, cool and humid air flows towards the Alps. Similar to a southfoehn situation, the pressure gradient in a northfoehn situation can also become quite steep; e.g. in Zurich measurements have been 15 hPa higher than in Locarno (again: figures are reduced to sea level).

During northfoehn, the build-up area [= *Staugebiet*] lies over the northern slopes of the Alps. The thickness of the cloud cover decreases with increasing distance from the Alpine ridge. Over the Jura Mountains, the sky normally clears up; consequently, the probability of precipitation diminishes. During northfoehn, the maximum of precipitation is registered in the central and eastern parts of the northern Alpine slopes; but the rainfall is not as heavy as during southfoehn over the southern Alpine slopes. The weather activity in western Switzerland is lower than in eastern Switzerland because the influence of the above-mentioned high-pressure cell is stronger in the west.

The sky is mostly heavily clouded in the Valais and the Grisons, in certain cases there is even a little precipitation, especially in the Grisons. Further south, the clouds diminish more and more and south of the Biasca-Bergell-line, the sky is practically clear. Foehn rotors and lee waves also develop during northfoehn.

Northfoehn flows now and then as far as the Po Plain; very rarely it even reaches the Gulf of Genoa.

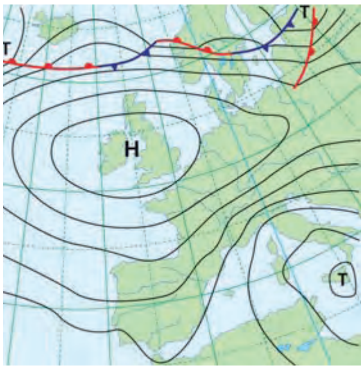


By flowing towards the Alps air masses are lifted a bit, hence are cooling, hence condensation is starting and clouds are forming in the build-up area. This far reaching phenomena is well shown in this figure as well as the dissolving of the clouds by flowing over the Alpine ridge because the air masses are heated up adiabatically.

Two pictures of a cumulonimbus capillatus (cf. p. 15).

1) Beside the typical anvil head (top left), the roller of the thunderstorm is clearly visible. It is the "fingers of the hand" in the lowest, very dark part of the cloud. There, coming from the higher troposphere, the cold air literally falls under the warm air in the ground layer, which can cause tornadoes.

2) The rainfall on the left-hand side of the cloud base indicates the direction of its motion: The wind lifts on the right side as warm air bubble, cools down und falls back to the earth's surface on the front side of the cloud caused by falling hail and waterdrops.

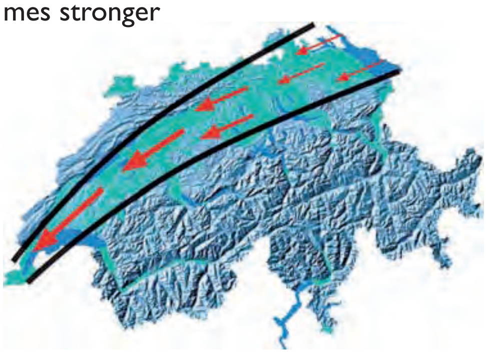


2.2 Bise Situation

An anticyclone (= high-pressure cell) lies in the Northwest or North of Switzerland. Polar Front waves pass along the northern boundary of this anticyclone over Scandinavia towards the East, without influencing the weather in Switzerland. Low pressure lies over the Mediterranean. Please also read GGCH, p. 305, and look at the picture on p. 47 (low-lying fog).

Within a distribution of the pressure like this, Switzerland lies in a north to northeast current which is locally known as **bise.**

Flowing westward over the Swiss Plateau the bise becomes stronger

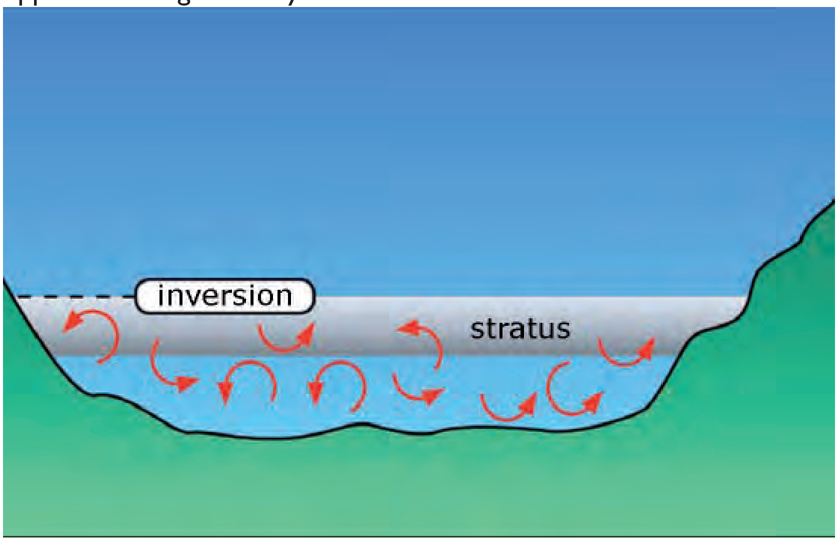


The distance between the Alps and the Jura Mountains becomes narrower from east to west, and is quite small in the region of Lake Geneva. The air blowing from the northeast is canalised between these two mountain ranges; therefore, wind speed increases towards western Switzerland. Hence, the gust maximum measured in Geneva is higher than 50 knots (= 1 knot = 1.852 km/h = 1 nautical mile per hour).

In summer, the continental air coming from the east is relatively dry. Therefore, there is fair weather with pleasant temperatures in the whole country.

In winter, the relative humidity of continental air streaming in is significantly higher. The vertical thickness of this layer with high relative humidity is between 500 and 2000 m; on top of it lies a warm and dry air caused by subsidence (= a macro-scale, anticyclonic, slow descent of air masses, accompanied by adiabatic warming and an increase of pressure). These two air masses are separated by a thin but prominent **inversion layer** [= *Inversionsschicht*] – it is a layer in which temperature increases with increasing altitude, which is – obviously! – in inverse relation to the normal case.

A cross-section through low-lying fog shows clearly that the inversion layer blocks any air-exchange between the the upper and the ground layer.



As a consequence of strong winds, a lot of turbulences occur within the humid ground layer. Therefore, the air particles rise and sink but are not able to push through the inversion layer; and with enough humidity a low stratus [= *Hochnebel*] develops in the ground layer. While the top of low stratus is defined by the inversion layer – and is seen from above as a 'low-lying fog' [= *Nebelmeer*] –, the altitude of the cloud base depends on the amount of humidity in the ground layer.

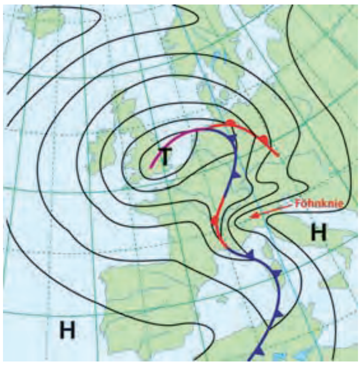
The ground layer with low stratus covers most of the Swiss Plateau [= *Schweizer Mittelland*], and, depending on the cloud top, the low stratus even intrudes some valleys in the Alps. The figure (top, next page) shows an average expansion of the low-lying fog with a top of 1,100 m asl.

In autumn or spring, low stratus can be temporarily dissolved during the daytime; in winter, however, the insolation is too low, and at this time of the year a thick cover of low stratus is therefore the rule throughout the day.

In a well-developed bise situation the low-lying fog [= *Nebelmeer*] at about 1,100 m asl intrudes even the bigger valleys of the Alps..

Top of the low stratus, seen as low-lying fog

Base of the low stratus



2.3 Southfoehn Situation

'Föhn' is a technical term and can be spelt 'föhn' or 'foehn'. Please also read also GGCH, pp. 52–5, 306; and AGG, pp. 158, 161/62 (lapse rates), 175.

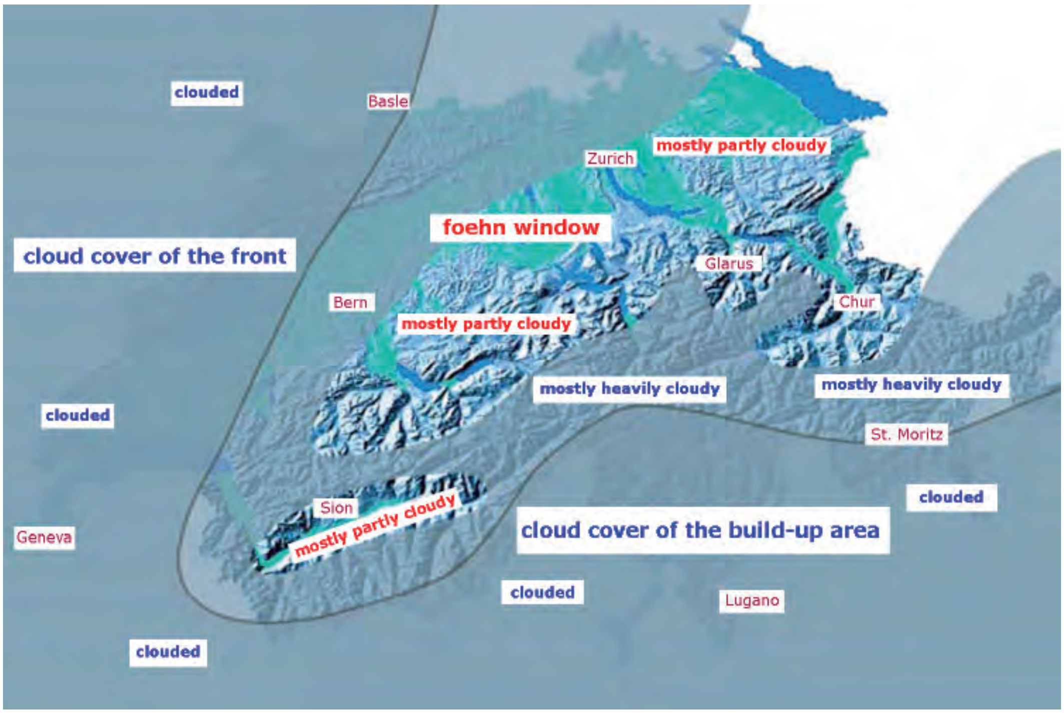
Foehn is defined as a wind which flows over a mountain range and sinks leeward into the valleys. As the air accumulates and rises windward of the mountain range, precipitation normally develops there. Every wind which flows over the Alps is a foehn, be it from the south or from the north. That is why we specify these winds by naming the direction: southfoehn and northfoehn.

Most importantly, southfoehn develops with a southerly by south-westerly high-drift over the Alps. The weather chart shows a typical structure: Low pressure is in the North-West of Switzerland over the North of France, the English Channel and the South of England. The cold front of the Polar Front wave has already advanced towards the East of France. A small high-pressure area develops over Northern Italy and the Balkans. The course of the isobars over the Alps shows the typical S-shape for this weather situation, the so-called 'foehn-knee'. The mean pressure in Zurich is 10 to 15 hPa (hectopascal) lower than in Locarno (figures are reduced to sea level); during a very strong foehn storm on 8/12/1982, the difference in pressure reached even 28 hPa.

A foehn situation can last from a few hours to several days and can show quite different intensities, i.e. stronger or weaker winds.

This overview shows the different reasons for clear or cloudy skys during a foehn situation: clouds in build-up area because of the wind-ward updaft, clear sky lee-wards (downdraft) and and frontally caused clouds from northwest.

Coming from the south, the humid and warm Mediterranean air rises along the southern slopes of the Alps and thereby cools down. First, some cumuli develop, then the cloud cover becomes denser and denser and finally turns into a stratocumulus which covers more or less the whole southern slope of the Alps (its cloud top lying between 4,000 and 6,000 m asl). Continual streams of humid air gradually make the cloud cover thicker (saturated-adiabatic lapse rate, SALR), till precipitation sets in.



In the North of the Alpine ridge, the air descends and gets warmer by compression (dry-adiabatic lapse rate, DALR). **Latent heat** [= *Kondensationsenergie*], which was released through the condensation (SALR) on the southern slopes of the Alps, cause the sinking air on the northern slopes to become 10°C and higher than in the Ticino at the same altitude. Of course, the air has also become much drier. The leeward clouds – i.e. those over the Alpine foothills and the Swiss Plateau – are often broken up completely by the warm-dry foehn air stream. Consequently, a part of the sky becomes almost cloudless. Looking from the lee to the peaks of the Alpine ridge, one can see this phenomenon in the form of a so-called **foehn wall** [= *Föhnmauer*], which is followed by the clear sky of a so-called **foehn window** [= *Föhnfenster*].

Gust maxima in the leeward Alpine valleys are around 70 knots, on the Alpine ridge itself even more than 100 knots.

As a consequence of the windward air uplift, typical lee waves develop leeward in the south stream up to 7,000 or even 9,000 m asl. On the wavecrest of these lee waves, so-called altocumulus lenticularis [= *Föhnfische*] can develop (cf. GGCH, p. 53, figure «Schematisches Profil einer Südföhnströmung»). These cloud formation can be observed before the foehn breaks into the leeward valleys. Furthermore, in the lower levels, mostly below the Alpine ridge, so-called foehn rotors (i.e. rollers with a horizontal axis) are formed in certain locations, e.g. over the Walensee. Up- and downdraughts faster than 25 m/s (= 90 km/h) have been measured in these rotors.

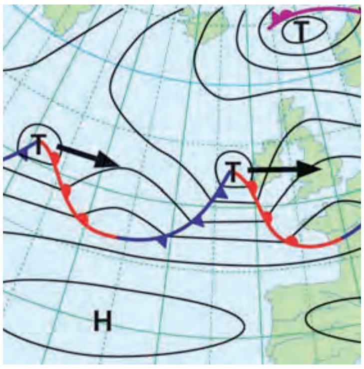
Foehn wall in the area Tödi–Clariden on the 8/12/82; foehn rotor in the foreground

On the windward side, i.e. the South of the Alpine ridge, the weather is really bad. With intensive precipitation, the base of the clouds lies only a few hundred metres above ground.

The Alpine ridge is shrouded in clouds, i.e. in the foehn wall; but it is only a bit to the north, i.e. leeward, where the cloud cover breaks up in the descending air: We are in the foehn window. In most cases, it covers central Valais, the Bernese Oberland, central and eastern parts of Switzerland, as well as the northern Grisons. Depending on the force of the foehn, the foehn window can expand further or include only the central and eastern Alpine foothills.

Foehn window over central Switzerland

West of the Basle-Montreux-line, the foehn is not able to break up the clouds, i.e., no foehn window develops. The sky in this region remains covered with clouds, possibly with some precipitation depending on the intensity of the approaching cold front.



2.4 West-Wind Situation

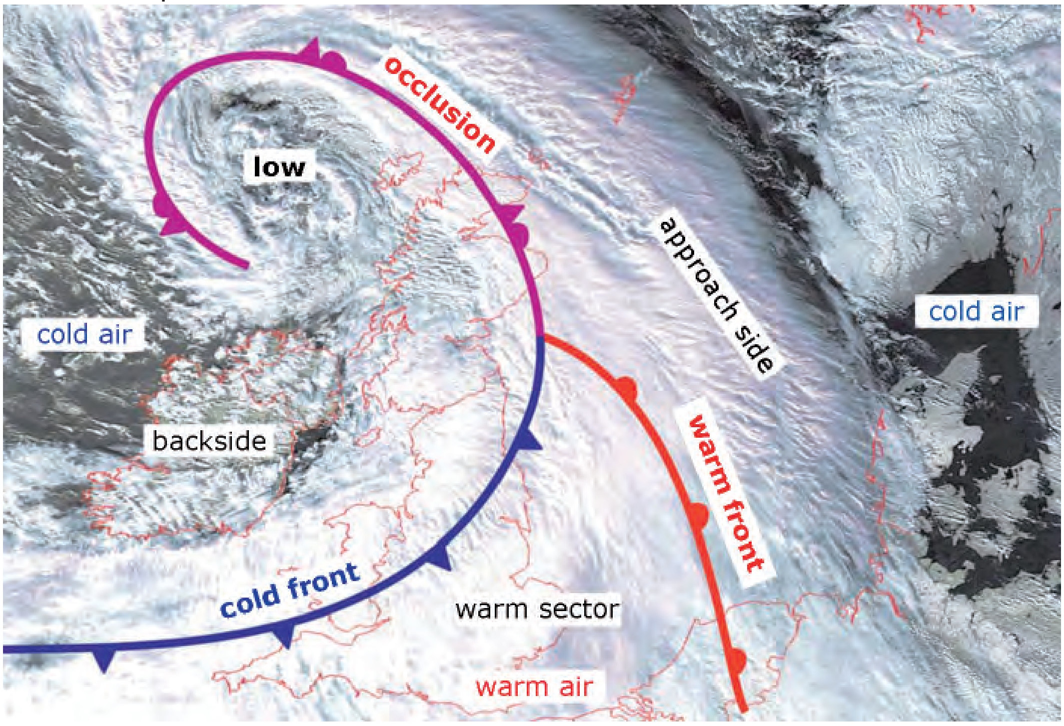
As west winds blow for approximately 220 days of the year (60%), it is by far the most important weather situation for us. Please also read in GGCH, p. 305.

Humid air flows in a stretched westerly high-drift (= west winds in high altitudes) from the Atlantic towards Europe. Embedded in this, Polar-Front waves connected to low-pressure cells drift over Central Europe at an interval of one or two days.

West-wind situations last a few days, sometimes even a week, and mostly occur between autumn and spring.

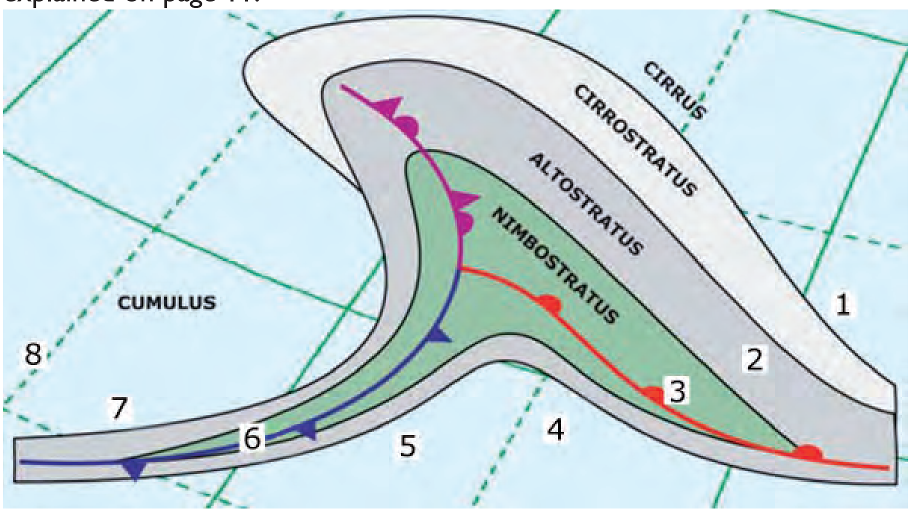
During west-wind situations, the weather in Switzerland is quite changeable. The weather activity is distinctly higher on the northern slopes of the Alps than on the southern slopes.

Satellite picture of a depression over Europe



The satellite picture (see left) shows a fully developed Polar-Front wave over Western Europe (cf. GGCH, p. 304; AGG, pp. 167–69). In front of the warm front, a vaste number of clouds have been developed in the warm, moist air by gliding over the heavier cold air. These clouds cover most of the North Sea. The area in front of the warm front is called **approach side** because of the ever-denser cover that builds in the sky during the approach of a warm front.

Distribution of the clouds in a frontal system (cf. depression above); the numbers are explained on page 11.



In the **warm sector** (zone between warm and cold front), the cloud cover brakes up with increasing distance from the low-pressure centre.

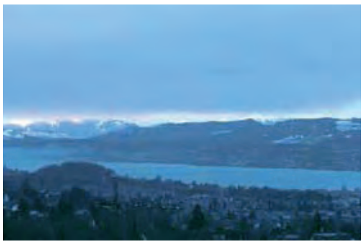
Compared to the warm front, the cloud cover along the cold front is much narrower. As a rule, in summer the development of cumulonimbus at the cold front is normal, in winter it is the exception.

In the area behind the cold front, known as **backside,** some cumuli might build up there, in the cold clean (high visibility) polar air, especially during the daytime. As it is the typical weather behind the cold front, it is the so-called backside weather [= *Rückseitenwetter*].

The spatial distribution of typical cloud formations along a Polar-Front wave are pointed out in the figure above, «distribution of the clouds...» (p. 10). The greenish part marks the precipitation area. Numbers 1–8 in the chart apply to the following pictures of clouds during the passage of a Polar-Front wave:

(1) Approaching cirri from West announce the coming of the warm front. They develop slowly into become a layer of cirro-stratus which …

(2) … becomes thicker while its base sinks; it then gradually changes into altostratus. The cloud cover sinks further and light precipitation starts. Again, the altostratus changes …

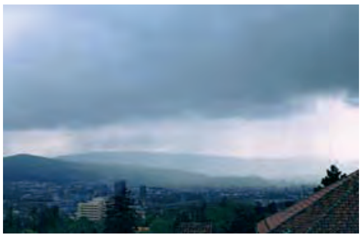


(3) … into nimbostratus, the precipitation becomes heavier and continues for several hours while low stratus-wisps [= *Stratus-Wolkenfetzen*] cover the sky. After the passage of the warm front, the precipitation decreases …

(4) … and the temperature rises. We are now in the warm sector. Scattered stratus clouds drift through the sky. Looking West …

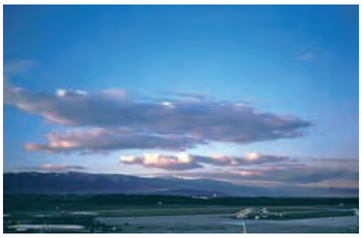
(5) … the huge thunderclouds (cumulonimbus) of the summer cold front are now visible. After a short while, …

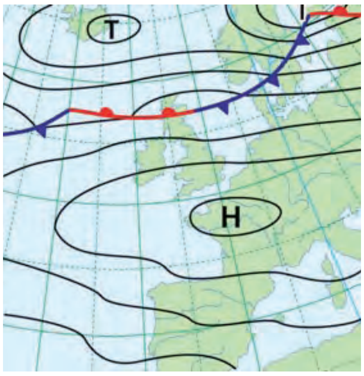
(6) … the sky is already covered with clouds. Thunderstorms and strong gusts accompany the passage of the cold front. The wind direction turns from southwest to northwest and …



(7) … the sky clears up. In the cool polar air behind the cold front, some cumuli develop during the daytime (thermal cause); sunny periods change with scattered showers, or even thunderstorms. Towards the evening and/or with the approach of a small high-pressure cell – usually between two Polar Front waves – …

(8) … the cumuli flatten out and change into stratocumulus banks [= *Wolkenbänke von* …] which gradually dissolve. After a short calming down, the warm front of the next Polar-Front waves already follows. West-wind weather means a continual change of weather.





2.5 Anticyclonic Situation

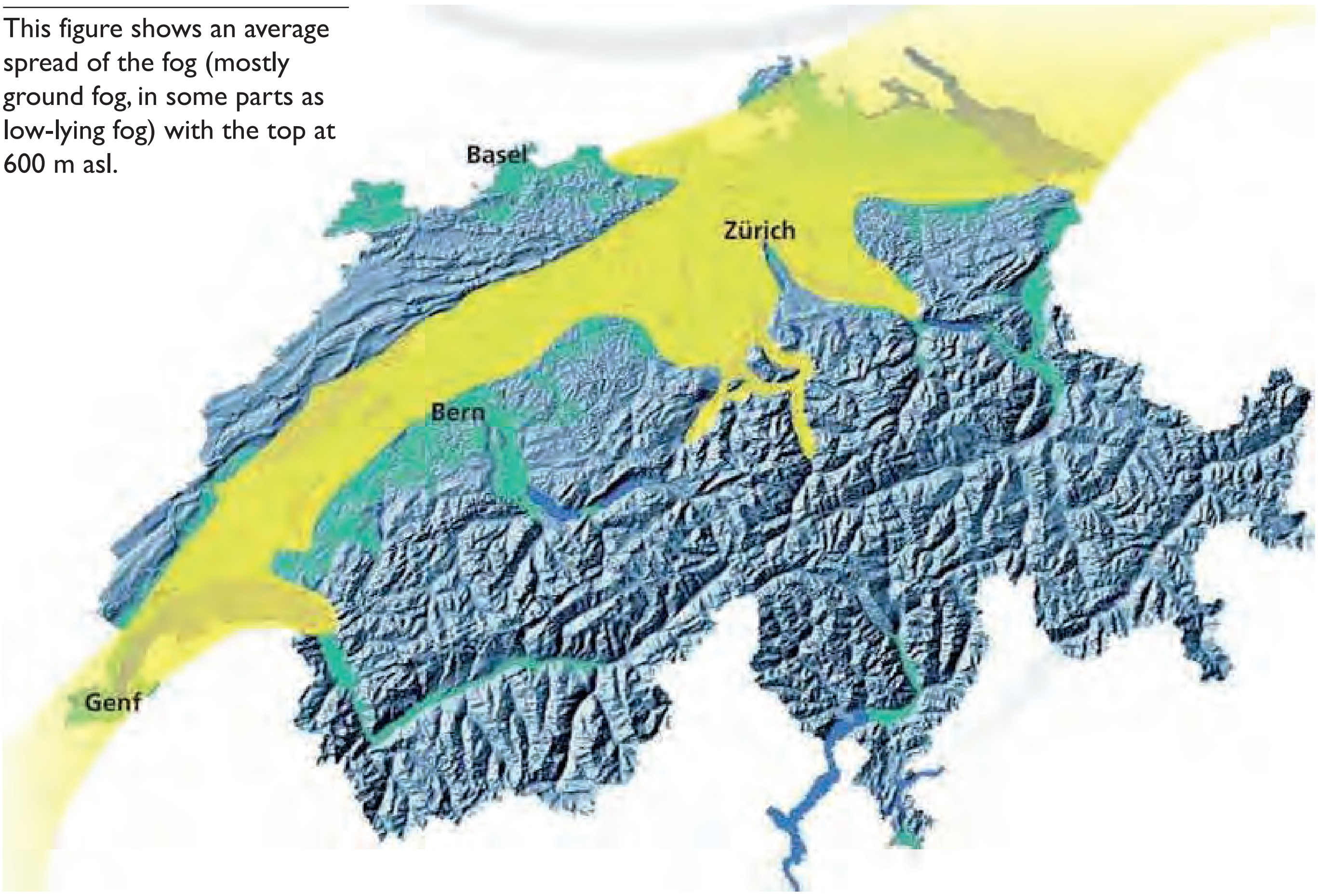
Please also read in GGCH, p. 306, to get informed about this convective weather situation.

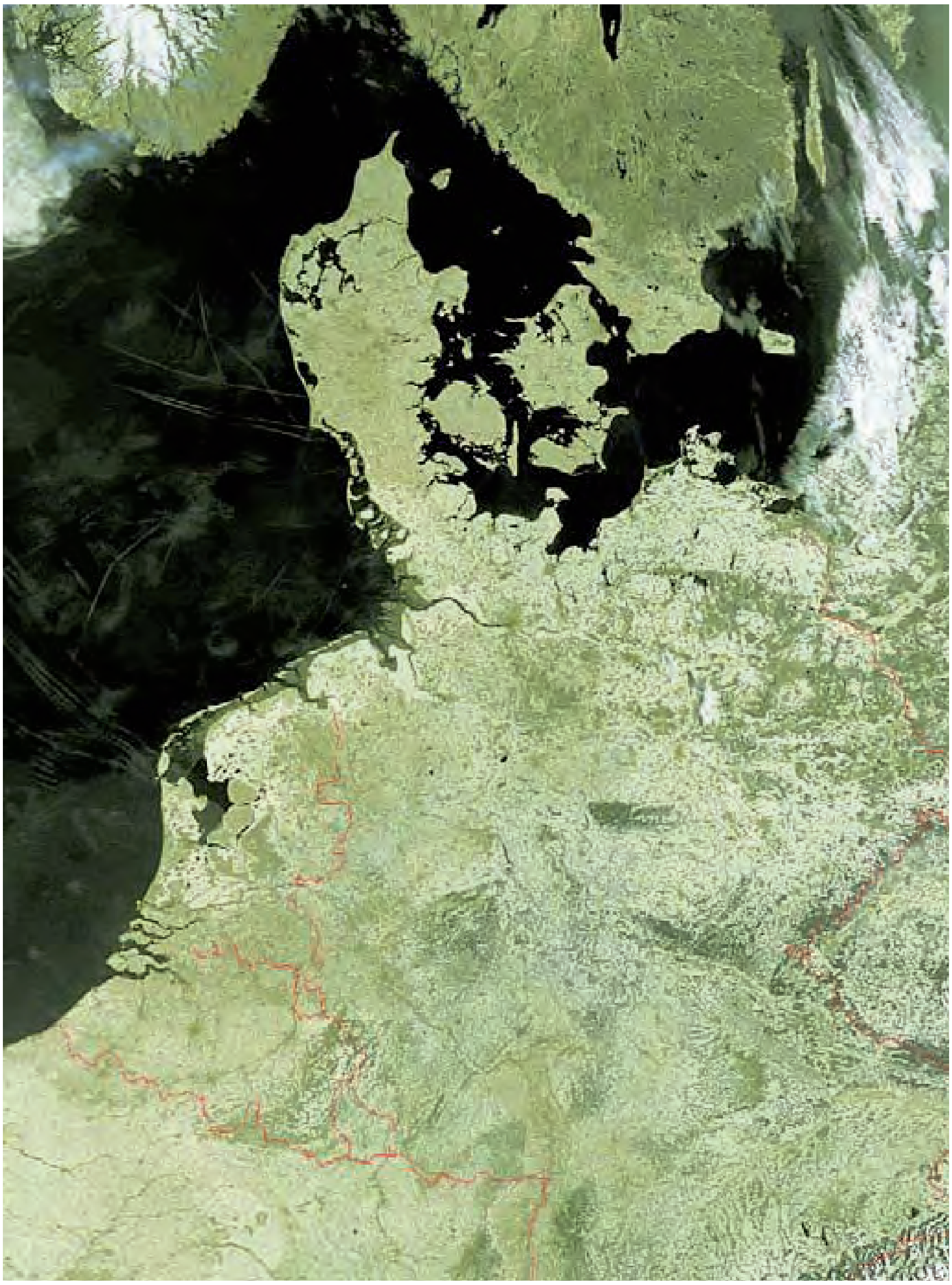
The weather chart shows an anticyclone centred slightly west of Switzerland. Almost no winds are blowing in the anticyclone because of small pressure differences (= almost no pressure gradient). Polar-Front waves are moving from the Atlantic northwards around the anticyclone towards Northern Europe, without influencing the weather in Switzerland.

In the anticyclone, the air masses are descending slowly and on a large scale (subsidence). The descending air becomes warmer by compression, hence relative humidity decreases (so it is bound to be below 100%), and hence clouds break up. Anticyclonic areas are therefore regions of fair (dry!) weather which move only very slowly away and give us periods of good weather from a few days to several weeks. In winter, the earth's surface cools down significantly in an anticyclonic situation. It cools down the ground layer in which extensive fogbanks develop; these cannot dissolve during the daytime between November and January. The average thickness of these fogbanks is 200 m.

The satellite picture on the next page clearly shows the anticyclonic influence. Extensive parts of Western and Central Europe are practically cloudless. The snow-covered Alps as well as the larger Swiss lakes stand out clearly. Even condensation trails (cirrus aviaticus) [= *Kondensationsstreifen*] can be seen over the North Sea.

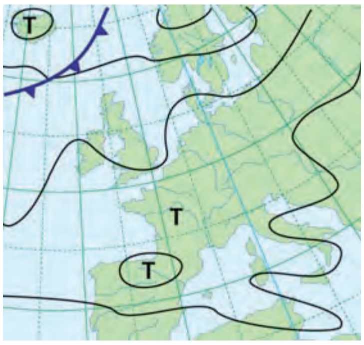
This figure shows an average spread of the fog (mostly ground fog, in some parts as low-lying fog) with the top at 600 m asl.





Satellite picture (false colours) of Europe during an anticyclone situation; over the dark water of the North Sea (on the left-hand side) cirri aviatici can well be seen.

During an anticyclonic situation, except for the temperature, no big changes can be expected in the Alps. But in the lower regions of the northern slopes, the seasonal differences are distinctive: In summer, fair weather predominates – visibility is probably reduced by haze [= *Dunst durch trockene Aerosole wie Russ und Staub*] –, but in winter, the lower regions are immersed in a low-lying fog, i.e. covered with low stratus.



2.6 Flat-Pressure Gradient Situation

Please also read in GGCH, pp. 51, 306, and AGG, p. 175, to get informed about this convective weather situation.

There is almost no pressure gradient (= difference in pressure between two points) over Western and Central Europe, i.e., the isobars on the weather chart are far apart. The horizontal air motion (= advective winds) in the troposphere is minute, convective winds can develop as soon as the sun causes a small pressure gradient (= thermal low and high cause thermal winds, e.g. mountain and valley winds).

Consequently, flat-pressure gradient situation is typical of a summer weather situation. In contrast to an anticyclonic situation, there is no subsidence in flat-pressure gradient situation, hence the uplift of warm air bubbles is not slowed down, and hence cumuliform clouds (cf. pictures below) can develop easily.

The clouds during a flat-pressure gradient situation show clearly the short-term weather development. Therefore, being able to recognise the clouds puts you in the position of making your own reliable weather forecast.

Altocumulus Castellanus

Certain clouds indicate a high probability of thunderstorms: Altocumulus castellanus indicates an instable layers of the troposphere, i.e. good conditions for thermal air uplift (= buoyancy).

Cumulus Humilis

The earth's surface heats up according to its nature (e.g. snow, forest, water, rock, etc.). The highest temperatures are reached above rock, sand and ploughed fields. Above these «radiators», bubbles of warm air develop during the early afternoon due to intense summer insolation. If the difference in temperature as opposed to the surrounding air is high enough, the bubbles of warm air lift from the surface and rise because of their lower air density. These bubbles have a diameter of several hundred metres. As soon as a rising air bubble reaches saturation value [= *Sättigungswert*], the surplus water vapour begins to condensate (SALR). The small and cauliflower-like cloud with a flat base now developing is called cumulus humilis.

Cumulus Mediocris

During the daytime the temperature of the «radiators» rise, hence also that of warm air bubbles. The bubbles rise to ever-higher altitudes, and so the cumulus grows into a so-called cumulus mediocris.

Cumulus Congestus

The cloud grows further, becoming a so-called cumulus congestus, and reaches a vertical expansion of several kilometres.

Cumulonimbus Calvus

Above the freezing level, the cloud consists mainly of supercooled raindrops, and the number of ice crystals is still insignificant. As soon as the growing cumulus reaches an altitude in which the temperature is about –40°C (roughly 9,000 m asl), these supercooled raindrops suddenly freeze to ice crystals. The ice crystals also grow and, getting heavier, start falling through what is now called cumulonimbus calvus: precipitation starts, accompanied by electric discharges – thunder and lightning. The cumulus has now changed into a thundercloud, identifiable from the outside by the frayed top of the cloud.

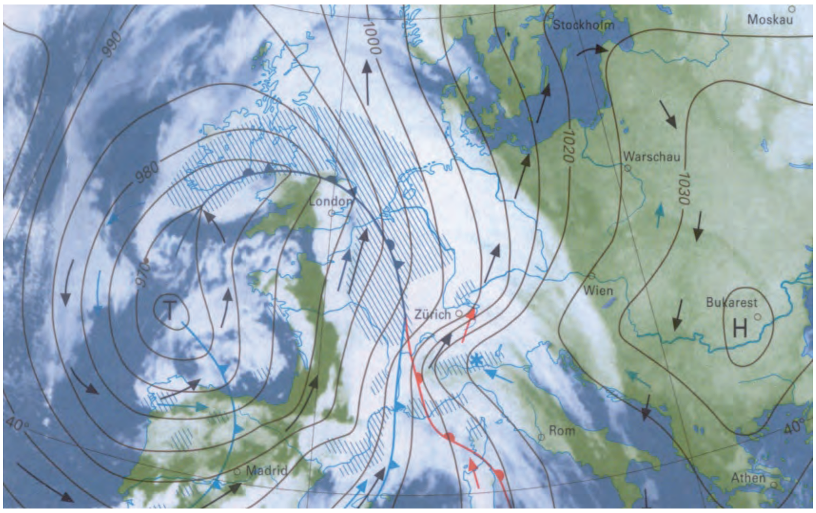
Cumulonimbus Capillatus

This type of cloud bumps against the tropopause (= top of the troposphere), its upper part expands and forms the typical anvil head [= *Amboss*]. With this the cloud now changes into a cumulonimbus capillatus. The intensive precipitation diminishes and during the following hours the cloud dissolves. And all we can eventually see are some cirri (as a rest of the anvil head) and some cumuli fracti (as a rest of the main part of the cumulonimbus).

Thermal thunderstorms mainly develop over the Jura Mountains and the Alpine foothills; they are scarcer over the Swiss Plateau. Diurnally, thermal thunderstorms occur most frequently during the late afternoon.

3. Revision

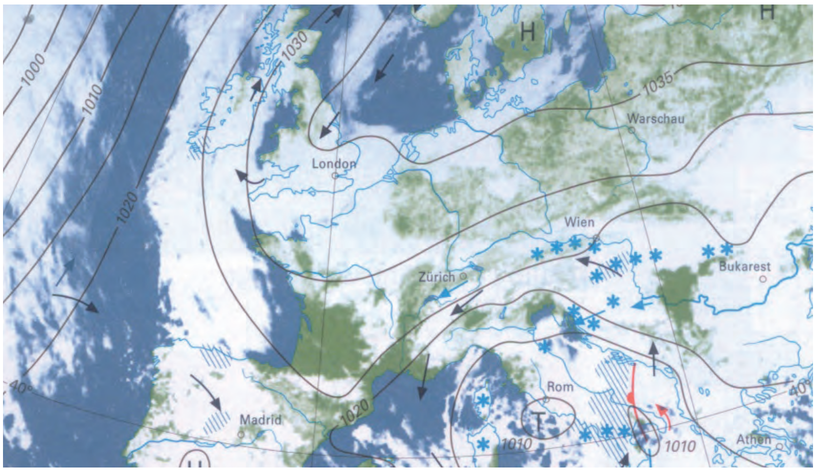
1. Study the satellite picture. Name the weather situation and justify your choice with your own keywords (i.e. do not copy from this skript).



1.1 Examine the origin of the air mass above Zurich.

1.2 Make a 24-hour forecast for Zurich according to this satellite picture.

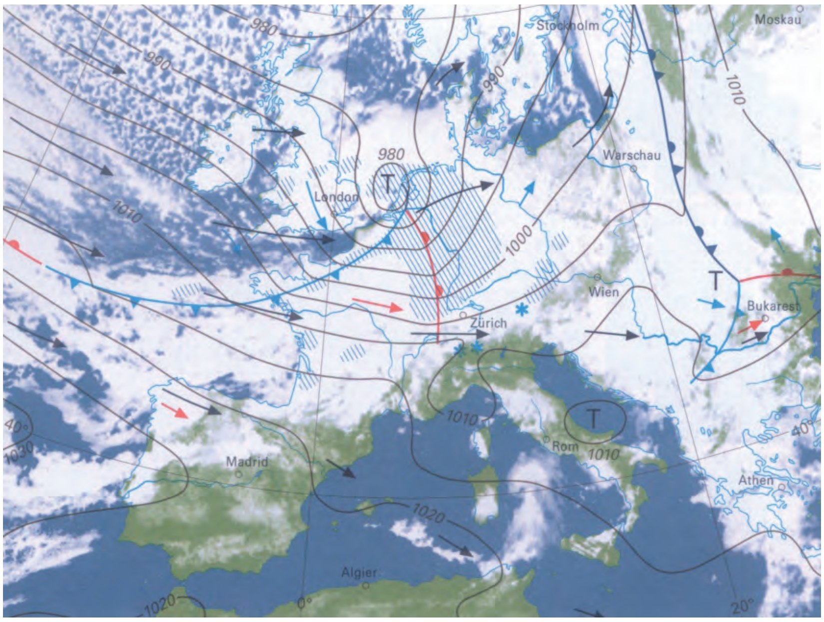
2. Study the satellite picture. Name the weather situation and justify your choice with your own keywords (i.e. do not copy from this skript).



2.1 Analyse whether this is an advective or convective weather situation.

2.2 Examine the convectivity of the cloud cover over the Swiss Plateau (cf. GGCH, p. 301/02).

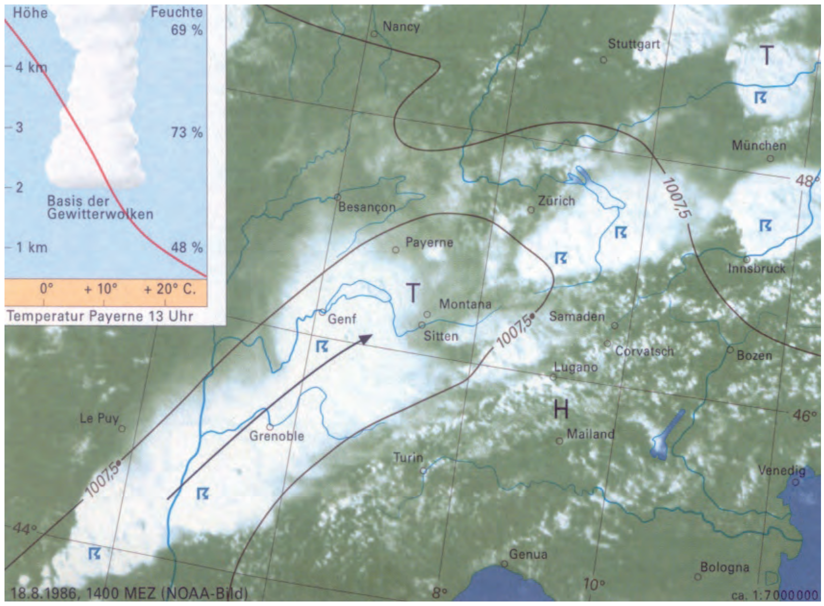
3. Study the satellite picture. Name the weather situa-tion and justify your choice with your own keywords (i.e. do not copy from this skript).



3.1 Analyse the (almost) clear sky over the Po Plain.

3.2 Make a 24-hour forecast for Zurich according to this satellite picture.

4. Study the satellite picture. Name the weather situation and justify your choice with your own keywords (i.e. do not copy from this skript).



4.1 Analyse whether this is an advective or convective weather situation.

4.2 Study the figure in the satellite picture (top left). Does it show a stable or unstable atmospheric layering? Explain the meteorological consequences of the shown layering.

5. Explain why the foehn is a rather warm air mass on the leeward side.

6. Justify in which seasons do west-wind situations most likely occur? Refer also to the seasonal movement of the global wind systems (cf. GCM).

7. What weather conditions have to be expected when Switzerland is in a bise situation? Distinguish between the Swiss Plateau, Alpes and Ticino.

8. Explain why there is clear sky and no cumuliform clouds during an anticyclonic situation, although then convective winds are usually predominant.

9. Explain the zone with clear sky during a foehn situation.

10. Contrast the weather on both sides of the Alpine ridge during a northfoehn situation.

4. Dictionary

Some special terms which have to be translated and spelt as written below.

(Schweizer) Mittelland	=	Swiss Plateau (always with 'Swiss')
Voralpen	=	Alpine foothills
Alpen(-haupt-)kamm	=	Alpine ridge
Jura	=	Jura Mountains
Föhnmauer	=	foehn wall
Föhnfenster, -loch	=	foehn window
Höhenangabe: m ü.M.	=	m asl (= metres above sea level)
Hochnebel	=	low stratus
Nebelmeer	=	low-lying fog
Nebelbank	=	fogbank
Bodennebel	=	ground fog
cumulusartige Wolken	=	cumuliform clouds
Wolkenobergrenze	=	cloud top
Wolkenuntergrenze	=	cloud base
Böenspitzen	=	gust maximum
Dunst (trocken)	=	haze
Dunst (feucht)	=	mist
Aerosole	=	aerosols; solid matter as dust, soot

5. Literature

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- EDK: *Schweizer Weltatlas*, Zürich, 2008; p. 16