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Remarks on some classes of Local Winds, a contribution to dynamical climatology

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1. *Classification of local winds.*

When studying local climates one often encounters wind, characteristic of the various climates and bearing special names.

These names may have their origin in the remote past e.g. föhn-favonius, a hot wind — or a special name may only be the word for wind or gale in the language of the country e.g. Purgan = gale — or it may indicate the direction from which the wind blows, as in the case of the names of many winds round about the Mediterranean.

We will not enter here upon extensive wind-systems such as trades and monsoons, nor upon tropical cyclones, or upon ordinary phenomenae such as land-, sea-, mountain- and valleybreezes (although these too may have special names in many cases) nor upon certain squally thunderstorms like the Tornadoes of West Africa and the Sumatras of the Straits of Malacca. All other air-currents characterised by a special name, we shall call local winds.

The fact that these local winds are known by special names at all shows that they have certain striking peculiarities, which vary for different winds and generally belong to one or other of the following categories:

1. Great force, special direction or high frequency of the wind.
2. Sudden rising of the wind in the form of a heavy squall.
3. Extreme high or low temperature of the supplied air.
4. Extreme high or low relative humidity of the supplied air.
5. Hydrometeors or sand and dust carried along by the wind.

Local winds mostly show several of these properties at the same time.

In most textbooks on climatology local winds are treated geographically. This has the advantage, that every wind is discussed in connection with other climatological properties of a region. It has however the meteorological disadvantage, that by this method the physical analogy between local winds occurring in different regions is not clearly exposed. It may be of some use to consider local winds from a physical point of view. We shall therefore endeavour to classify them according to the origin af their peculiar qualities. This may, perhaps serve as a small contribution to the dynamical climatology of those regions where these local winds occur.

A local wind as we define it may, theoretically speaking, be due to four causes:

A. To a special field of pressure. (See catagory 1).
B. To the relief of the surface of the earth.
C. To the fact that the wind supplies air from the source-region of an air-mass.
D. To the passage of a front.

The following table gives the various causes with examples:

A
- a. Strong Winds or gales (Elephanta)
- b. Winds with special direction (Portuguese Trade)
- c. Winds showing great frequency (Etesian winds or Meltems)

B
- a. Warm air-current descending along a mountain slope (Föhn)
- b. Cold air-current descending along a mountain slope (Bora)
- c. Air-current accelerated in a valley (General Mistral)

C	a. Arctic air	(AA)		(South Pole Blizzard)
	b. Polar air	(PA)	continental PA (cPA)	(Buran)
			maritime PA (mPA)	(Tramontane)
	c. Tropical air	(TA)	cTA	(Scirocco)
			mTA	(Zonda)
	d. Equatorial air	(EA)		(Zonda)
D	a. Warm front			(?)
	b. Cold front			(Pampero)

We shall now briefly discuss the different possibilities.

2. A specal field of pressure.

Winds under this heading are usually of little importance meteorologically speaking. The special field of pressure may arise from various causes. Such as the influence of a monsoon (Elephanta at the Malabar coast) or the fact that the wind is one of the trade winds (Portuguese Trade).

Also gales in front or behind depressions may be called by a special name. Many examples of these winds occur in maritime litterature.

We mention the Seistan or Hundred twenty -days-wind in Iran and the Meltems of the Eastern Mediterranean both showing a great frequency as well as a very defined direction and the South Easter of California, the Kona of the Hawaiian Archipelago and the Lan San of the New Hebrides as examples of gales. It would be easy to give many more examples.

3. The relief of the surface of the earth.

In all mountainous countries the general air-currents are deviated in some way or other. Often a wind acquires certain characteristic qualities by these processes so that we can speak of a local wind.

BA) Descending hot winds.

The almost standard example of a hot descending air-current is the souherly Föhn on the North side of the Alps. The striking fact that cold air is replaced by descending warm air was a very difficult phenomenon to explain in times gone by.

After much speculation (descending anti-trade-Sahara-wind) the origin of the Föhn and its peculiarities were discovered by Austrian and Swiss meteorologists.

The generally accepted view is as follows:

We have to distinguish two Föhn-phases.

The first one, the anticyclonic Föhnphase is characterised by an anticyclone with small vertical temperature lapse-rates over the Alps. When this anticyclone is attacked by depressions, approaching central Europe from the West, the air begins to stream away from the valleys on the northern side of the Alps. The lack of air coming into being in this way is counteracted by a supply from the slopes, and the dry-adiabatically descending air causes the temperature in the valleys to rise. As the small temperature lapserate is an essential condition the anticyclonic Föhn-phase is especially a winter phenomenon.

The second one, the cyclonic or stationary Föhn-phase, which may arise from the anticyclonic phase, is characterised by condensation and precipitation on the windward side of the mountain-ridge and a dry adiabatic descent on the lee-side of the air warmed by the condensation. Characteristic is the so-called Föhn wall (Föhnmauer). In the Alps the stationary Föhn phase occurs especially during strong cyclonic activity, i.e. during autumn and winter.

This does not mean that there are no Föhns at all in summer, but there is generally a cold season maximum.

Some authors explain the Föhn phenomenon in another way. They maintain that, owing to dynamical causes strong upper winds blow down into the valleys from time to time, causing a temperature-rise. This theory is more suitable for the explanation of the „Föhnpauses", periods during which the Föhn does not occur. Very likely both processes take place. Figure 1 shows a wea-

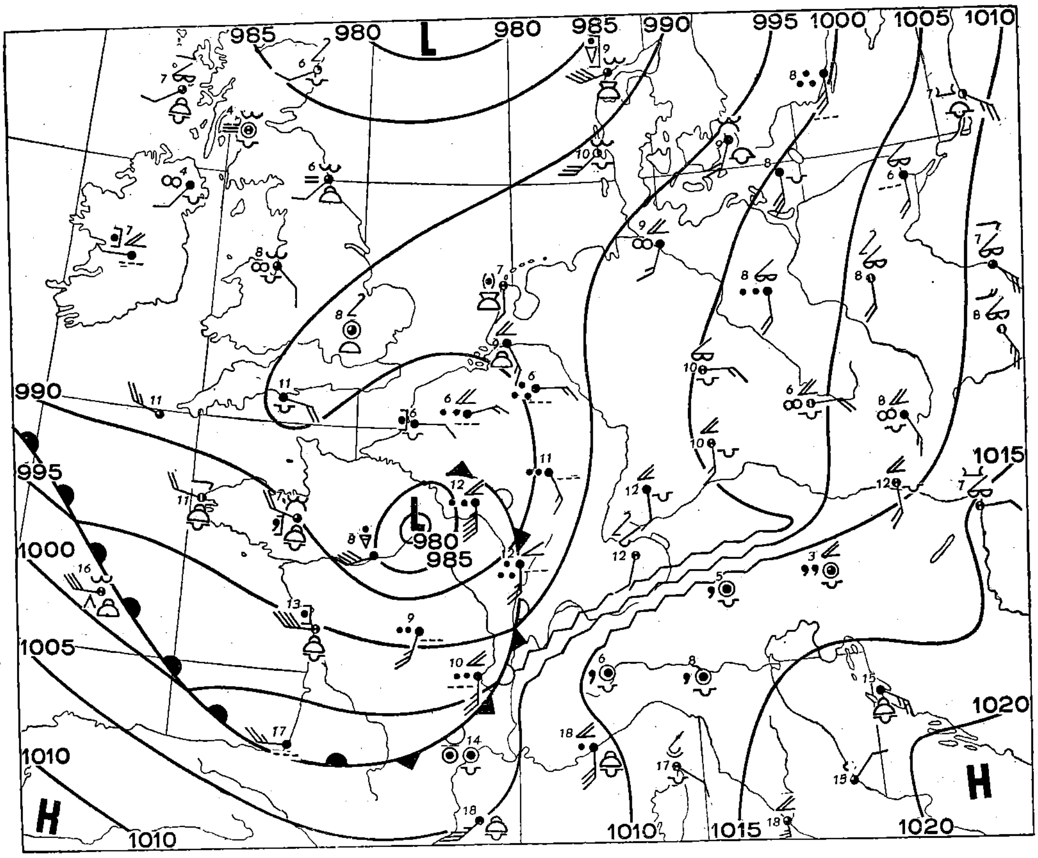

Fig. 1. Weather situation of November 21, 1938, 13.00 G.M.T. with stationary Föhn.

ther situation during a stationary Föhn-phase on the North side of the Alps. Föhn winds occur in nearly all mountainous countries, the stationary Föhn being the most common. Examples are the Autan of Central France, the Föhnwinds on the coasts of Greenland, the Hot winds of the United States among which the Chinook winds are especially famous, the Norther and Santa Anna of California, some cases of Northers on the south coast of Central America, the Zonda on the east side of Andes and several winds in the Netherlands East Indies of which the Bohorok in Deli is the most familiar.

In recent years the term anticyclonic Föhn was introduced for the vertical motion during subsidence in the higher levels of an anticyclone, in which case the air at the ground level is not heated. This anticyclonic Föhn is an example of the so-called free Föhn which originates in the free atmosphere without any influence from the relief of the surface of the earth. One should carefully distinguish between this anticyclonic Föhn and the anticyclonic Föhn-phase which it may precede in the Alps.

Bb. Descending cold winds.

The difficulty which presents itself when we try to explain these local winds of which the Bora of the Adriatic is the standard example, lies in the fact, that in spite of the dry-adiabatic heating the descending air is cold when it arrives down below. This is only possible when the vertical temperature lapse-rate along the mountain-slope exceeds 1° C per 100 m.

One does not always realise that this condition can be fulfilled in two ways :

1. The air at the foot of the slope is strongly heated by insolation while the unhindered air-currents at the top of the slope prevent any considerable heating there. The vertical temperature distribution is then of a nature as in figure 2. The descending air-current has Föhn characteristics

in the higher levels whereas it appears a B o r a in the lower ones. It follows from this as an essential condition for the occurrence of a B o r a in this case, that the height difference between the top

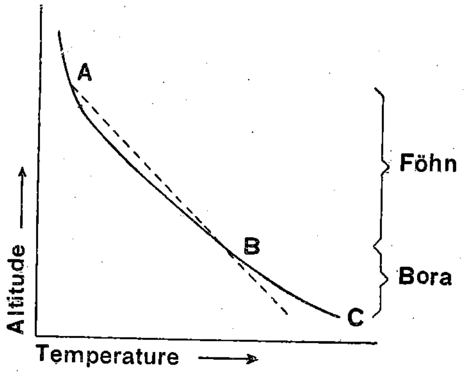

Fig. 2. Over-adiabatic lapse-rate owing to heating below.

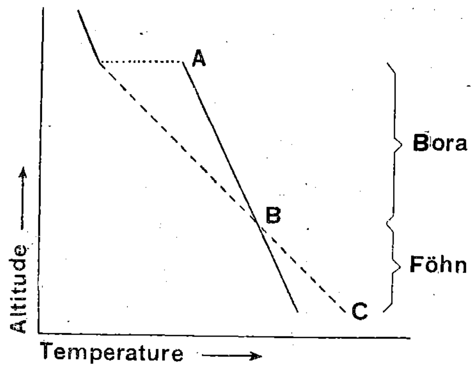

Fig. 3. Over-adiabatic lapse-rate owing to cooling above.

and the foot of the slope is rather large. The situation indicated here may occur for instance in equatorial regions. The B o h o r o k mentioned above sometimes brings about a cooling in the hot plains.

2. Secondly the overadiabatic lapse-rate along the slope may originate in a severe cooling of the air at the top of the slope by radiation or advection, while, in the meantime, the temperature down below does not change to any great extent. This may be the case when the foot of a slope runs along the sea-shore (non-coherent climatic regions).

From figure 3 we can see, that the descending air-current has B o r a characteristics in the higher levels but is a Föhnwind in the lower ones.

This double character of the descending wind occurs at the South coast of Central America

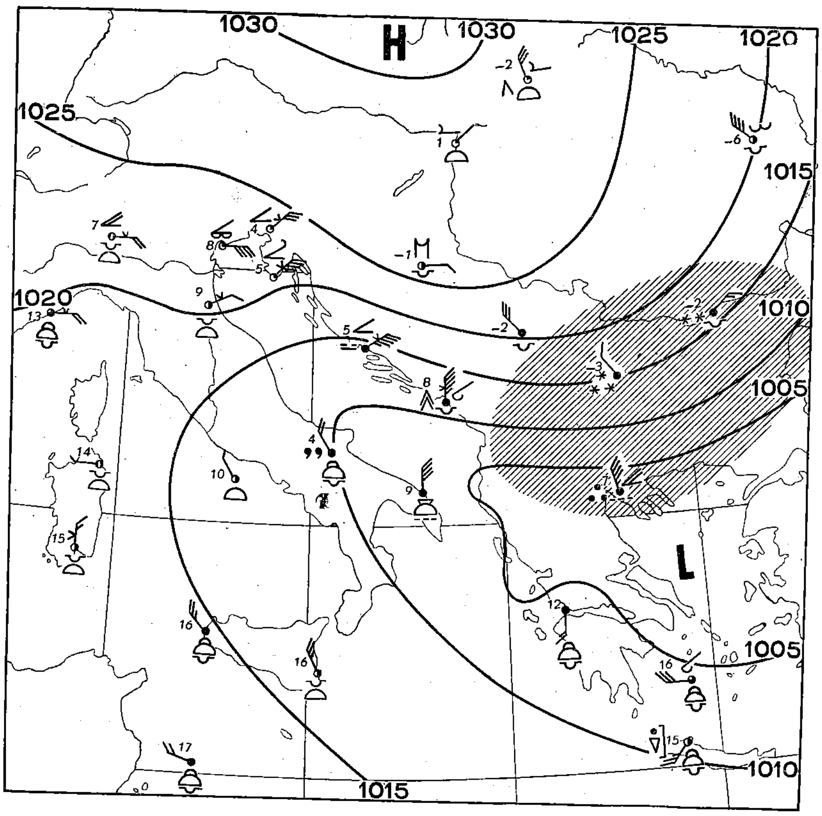

Fig. 4. Weather situation over the Adriatic of December 12, 1939, 13.00 G.M.T. during anticyclonic Bora.

for instance, where the N o r t h e r s are cold in the higher levels and warm in the lower ones.

If the B o r a-character of the wind is to be maintained down to sea-level, the height diffe-

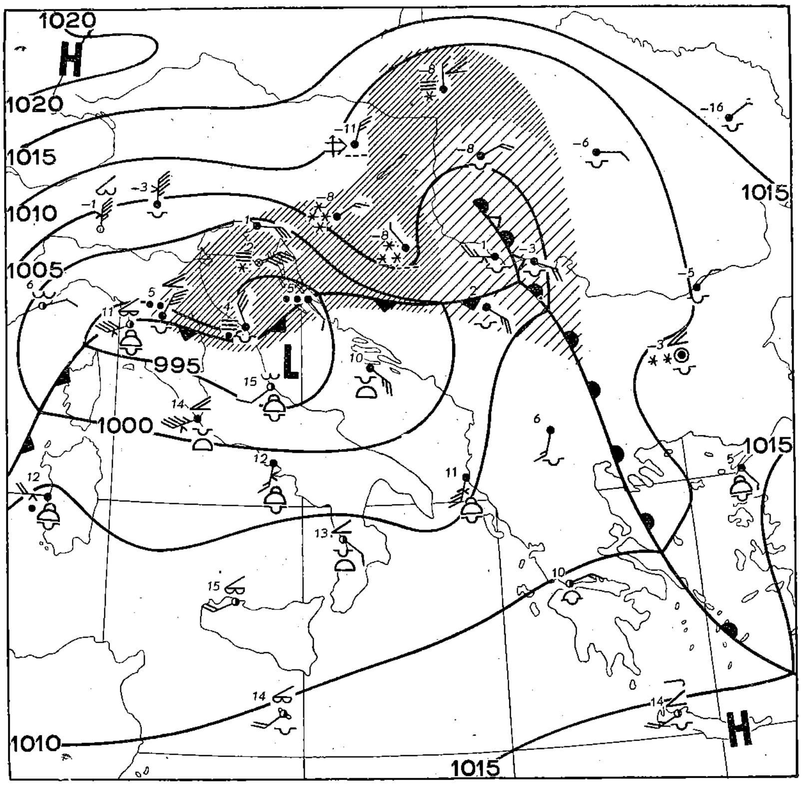

Fig. 5. Weather situation over the Adriatic of February 13, 1940, 07.00 G.M.T. during cyclonic Bora.

rence between the top and the foot of the slope must not be too large. A situation of this kind is present at the East coast of the Adriatic.

We can distinguish here between an a n t i c y c l o n i c and a c y c l o n i c B o r a. The former blows with anticyclonic weather and a clear sky. The latter is accompanied by overcast skies and precipitation as a consequence of a depression (fig. 4 and 5). The former is the most squally and loses its force close to the Dalmatian coast, while the latter is often perceptible on the Italian peninsula.

Other examples of cold descending winds are the l o c a l M i s t r a l (M i s t r a l l o c a l), which occurs in the Rhône-valley with anticyclonic weather conditions over Central and Western France, the B i s e in the French Alps, the K o s s a v a of the Balkan, the P o l a k e of Bohemia, the N o r t h e r s of the South coast of Central America and several winds along the coasts of Asia minor and the Arabian peninsula.

Bc. A c c e l e r a t e d w i n d s.

The l o c a l M i s t r a l must not be confused with the g e n e r a l M i s t r a l (M i s t r a l g é n é r a l) which sometimes occurs as far as the African coast.

The latter wind belongs to the group of accelerated winds because the air is forced to pass through a narrow valley, in this case the Rhône-valley.

Figure 6 demonstrates cleary how the isobars gather together in the neighbourhood of the Rhône-valley. Near Perpignan these winds are called T r a m o n t a n a.

The same effect arises when the air is forced to round an orographic corner (the W i l l y-w a w s at the South point of South America e.g.).

4. Local winds showing the qualities of an air-mass.

Air-masses are formed by the influence of several physical processes over homogeneous areas where the air remains stagnant for some length of time, so called source-regions. As

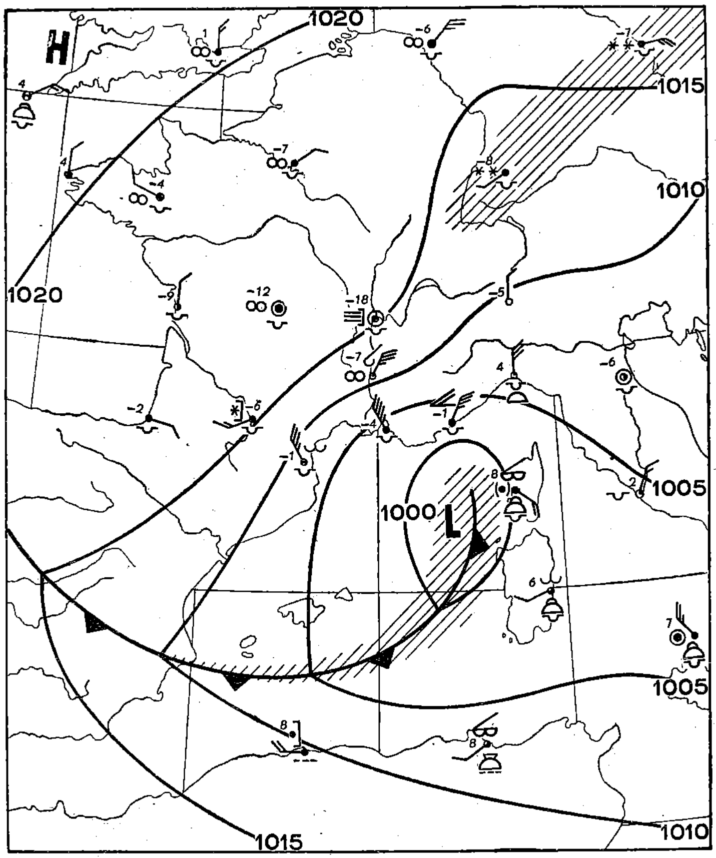

Fig. 6. Weather situation over S.W. Europe of December 24, 1938, 07.00 G.M.T. during Mistral général in the Rhône valley.

there is nearly always little wind in the centre of a source-region we find most local winds of this kind near its borders.

As shown in the table given above we can subdivide the winds belonging to this category into four groups, according to the air-mass they supply.

Ca. Local winds, which supply artic air, only occur in arctic regions. Well-known is the Blizzard in the Antarctic, which is characterised by extremely low temperatures and vast amounts of drifting snow.

Cb. Local winds, which supply polarair, can be divided in three groups:

α. the winds which supply cPA in winter.
β. those which supply cPA in summer and
γ. those which supply mPA.

cPA is exclusively found on the northern hemisphere so that the local winds of categories α. and β. only occur there.

α. Figure 7 demonstrates a situation typical for the origin of one of the most famous local winds, the Buran, showing the same qualities as the winds supplying arctic air, severe cold and drifting snow.

A weak depression in the Black Sea is sufficient to create the stronger gradient field

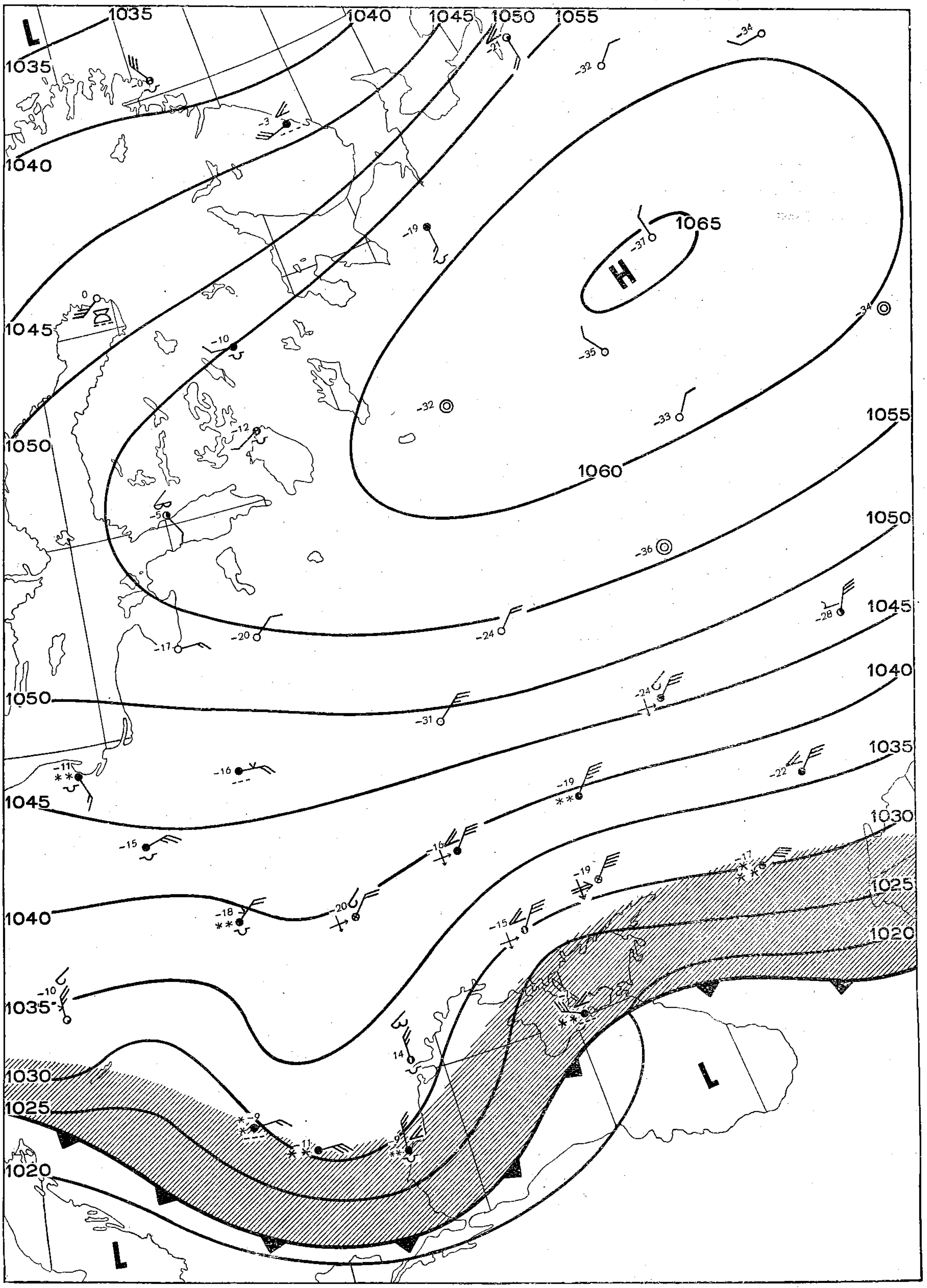

Fig. 7. Weather situation over Eastern Europe of December 17, 1938, 07.00 G.M.T. during Buran.

necessary for the origin of this local wind. In Northern Russia and Siberia it is often called Purga, especially during a snowfall.

The Blizzards of North America are due to an analogous situation, with depressions moving NE-wards over the South-eastern States.

In the Southern States and the Gulf people speak of Northers. In these regions the cold front which precedes the cPA is often the most spectacular phenomenon, and for that reason we can consider the Norther also as belonging to group Db.

β. An example of a local wind, supplying cPA in summer is the Karaburan, a hot dry North-eastern gale in Turkestan, which transports enormous quantities of sand by which even riverbeds are diverted.

γ. Winds supplying mPA have usually only slightly striking characteristics. Only some local winds in the Mediterranean supply mPA, the Tramontana e.g. its main feature being, its delicious freshness after the hot Scirocco.

Cc. Local winds supplying tropical air.

These can be divided into α. those that supply cTL and β. those that supply mTL.

α. Source-regions of cTL are to be found on both hemispheres, so that on both hemispheres local winds of this group occur with the characteristic properties: high temperature, low relative humidity and the transport of dust and sand.

Figure 8 shows a situation with a Scirocco, which supplies air from the Sahara. As the pressure is relatively low in this source-region, the field of pressure must change considerably to enable the cTA to leave the desert. This happens as a rule by the deep penetration of polar air to

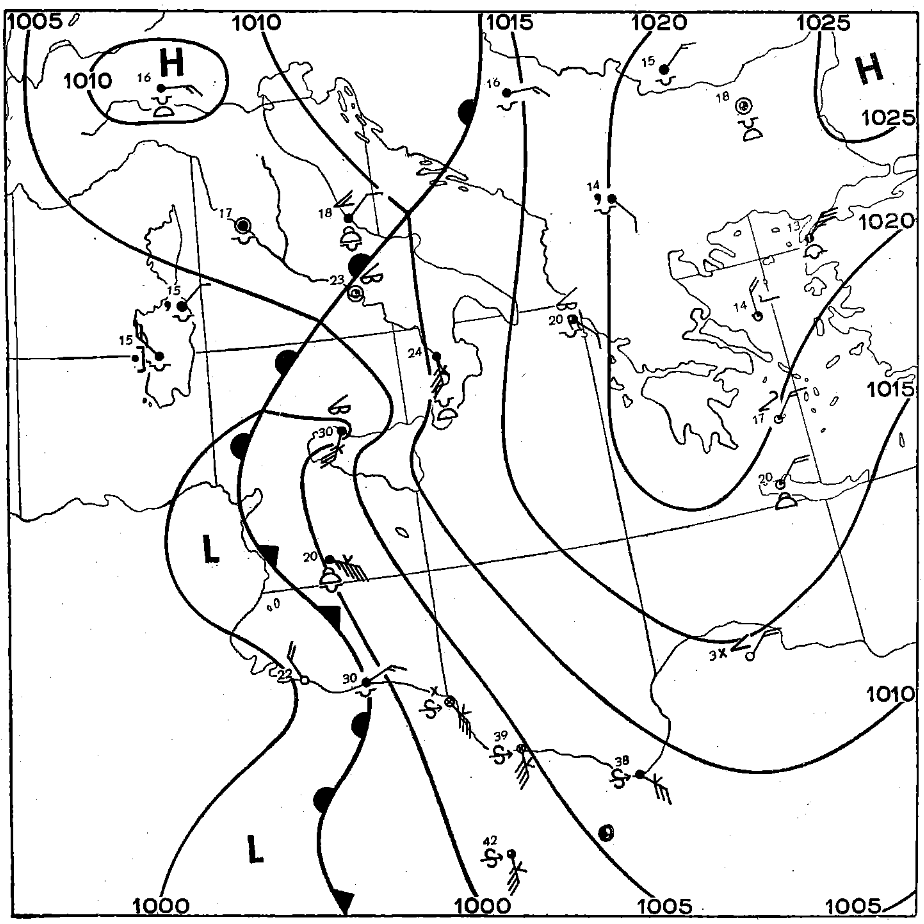

Fig. 8. Weather situation over the Mediteranean of May 2, 1940, 13.00 G.M.T., during a Scirocco.

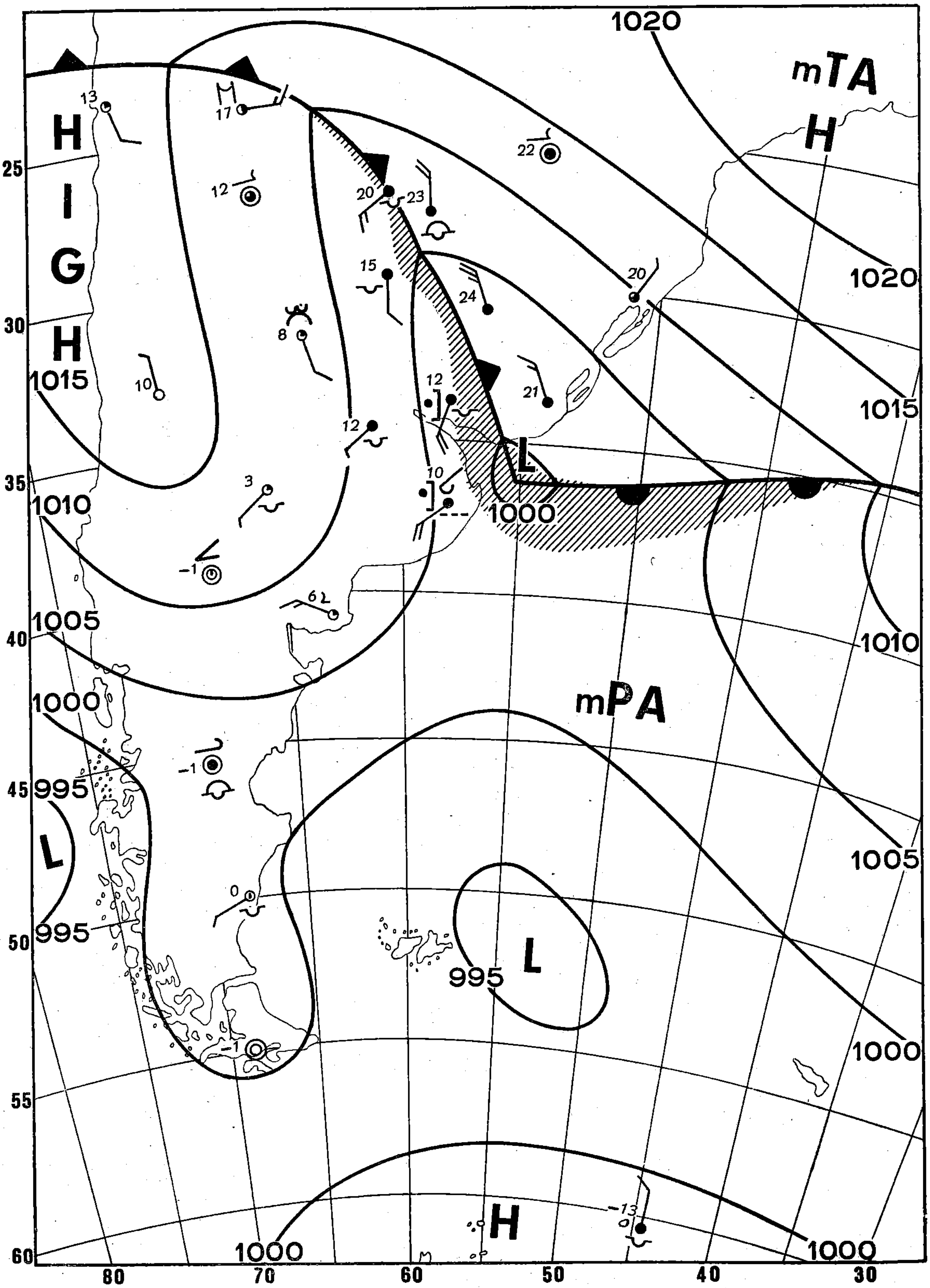

Fig. 9. Weather situation over South America of July 14, 1940, 12.00 G.M.T. with a Pampero developing.

the South. As the Scirocco moves over the Mediterranean, it loses its dryness and reaches Italy as an oppressive wind. This sort of local winds occurs all round Africa. The most familiar names are Khamsin in Egypt and on the Red Sea coast, Namib in South-West Africa, Harmattan in the Guinea coast, Leste in West Africa, Chili in Tunesia and Gibli in Tripolitania.

On the Southern hemisphere the Australian Brickfielder presents an example of a local wind supplying cTA.

In the deserts themselves squalls sometimes occur due to instability of the air strongly heated from below. These squalls often create a small cold front which is marked by a thick wall of dust (Haboob, Simoon).

β. Winds supplying mTA have no particulary striking characteristics, just like the winds which supply mPA. One of the most familiar is the Zonda which supplies sultry mTA to the North of Argentine.

Cd. Local winds supplying equatorial air.

All local winds in equatorial regions supply EA. Generally, however, their characteristic properties are great force or high frequency or the winds may show Föhn characteristics so that they must mostly be grouped under A or B.

Sometimes EA leaves its source-region and then the wind makes itself noticeable by its oppressive character. The Zonda of Argentine for instance, in some cases supplies EA from the Amazone region.

5. *Local winds connected with a frontal passage.*

Generally the most important characteristic of a local wind of this group is its sudden start, at times accompanied by a squall.

Warm fronts show these characteristics rather seldom. Local winds originating in a warm front passage are, therefcre, not known.

Local winds connected with the passage of a cold front will occur more especially when the temperature difference between both adjacent airmasses is great.

This is often the case on the Southern hemisphere. Owing to the existence of the large antarctic continent and the cold Westwind drift cold air is present at rather low latitudes and, moreover, the meridional exchange of air can proceed unhindered as mountain ridges running west-east are scarce.

The most characteristic examples of local winds of this group are therefore the Pampero of South America (fig. 9) and the Southerly Burster of New South Wales. Their most striking properties are: sudden start, great fall in temperature, often heavy precipitation accompanied by thunderstorm. If the cold air beneath the frontal surface descends its accompanying greater velocity from higher levels causes a heavy squall.

As we have seen already the Blizzard-Norther of North America penetrating far into the South may change its nature gradually from Cb_{α} into Db.

6. *General survey.*

It is clear that the above discussion is only very schematical. A wind classified under A, for instance, will always supply some air-mass where as, on the other hand, winds classified under C may be of considerable force and are, of course, also due to some field of pressure. Nevertheless, any wind may be classified under one of the four categories. For example:

The Bora in the Adriatic only blows when cPA is present over the Balkan peninsula. It is clear, however, that the Bora belongs to case Bb, i.e. that it is a typical descending cold wind.

The above lines have been written to show one of the possibilities for dealing with climatological subjects more systematically. Descriptive climatology would benefit by it. After all, it is of little importance whether the system here proposed is applied or a better one, which may still be developed without much difficulty.

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