A report on glider-pilot activities to document leewave-events in northern Germany and their aims

Joerg Dummann
An der Alten Warte 20, D-34127 Kassel
dummann@mittelgebirgsleewelle.de

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Abstract

A brief outline of the orographical, meteorological and infrastructural circumstances of wave-flying in the region of the lower mountains of Northern Germany is given, completed by a short historical overview. Aims and methods of a glider-pilot-initiative for gathering information on aerial waves are presented. Some effects intrinsically affecting the resulting observations by using gliders for the exploration of the phenomenon are mentioned. Statistical summaries of the gathered data are given, as well as descriptions of some interesting observations. Modified didactical concepts are presented for the understanding of the foehn-phenomenon, which take into account actual scientific insights; and for the comprehension of the kinematics of aerial gravity waves by a simple and vivid, plausible and logical attempt, which is intended to initiate a specialized discussion to the question of its scientific adequateness. Finally a summary of possible future activities of the glider-pilot-initiative is provided.

Introduction

The orography of northern Germany directly south of the coasts of the North and the Baltic Sea is characterized by extended plains. This landscape shows only negligible differences in heights, smoothly formed by the glaciers and rivers of the quaternary. Sharply divided from this region, lower mountains dominate the scene southwards. The valleys and heights developed as layers of trias, which mainly build up the surface of the northern wave-region, were folded up during later geological periods. This kind of genesis generates many more ridges than single peaks. These reach heights from about 300m to 400m MSL i.e. around 100m to 200m – or less – relative to the valley floors. Only few elevations rise up to more extended heights: the Harz-Mountains generally around 600m (“Clausthaler Hochflaeche”), culminating in the Brocken Massive at 1.140m, the Hohe Meissner at 750m, the Thüringer Wald at 980 m, the Rhoen at 930m, the Fichtelgebirge at 1050m, the Erzgebirge at 1.200 m (see fig 1).

The ridgelines in the region northwest of the Harz mountains (called the Weser- and Leine-Bergland) are mostly aligned from southeast to northwest – due to a specific tectonic load, which also distinctly influenced the geological ascent of the Harz-mountains. This washboard-like orography is especially suitable for generating leewaves. In 1961, Prof. Walter Georgii aptly titled this region the “Northern Germany wave flight centre” (see fig 2).

Under these orographic conditions but also in connection with the ability of certain airmasses to resonate with triggered waves or not, and allowing vertical and/or horizontal propagation of them or not, it is mainly southwesterly and northeasterly weather situations which lead to the occurrence of leewaves.

In northern Germany, soaring sports are structurally dominated by clubs, even though nowadays more and more private owners are becoming involved. Nevertheless it is still a predominantly non-commercial infrastructure. With volunteer-commitment helping to cut costs, wave-flying in the lower-mountains is not a pastime to be enjoyed by only a few individualists, but has turned into a popular aeronautic sport. Glider-pilots come from all walks of life; their qualifications and motivations reflect this variety.

Seen before this historical backdrop, some outstanding aeronautical achievements: in the sixties of the 20th century some pilots reached altitudes around 5.000m MSL in resonant waves of the Hasselberg-Suentel-Deister-System, hilly ridges with heights of 300m MSL situated a few kilometers south of Hannover. In 1968; W. Reinhard flew the record-altitude of 7.800 m MSL in the lee of this resonant wavesystem using a Scheibe “Zugvogel”[a]. Excited glider pilots generated a real leewave-hype at that time, but the further spreading of the activities suffered from some unfortunate circumstances: in the midst of the wave area there was a political frontier dividing Germany – with a broad “Air Defense and Identification Zone”, which made wave-flights an impossible act. And club-gliders for the most part were built of wood and fabric so that they needed extended maintenance by the clubs during autumn and winter, when the waves develop best.

At this time Carsten Lindemann began his efforts to investigate the leewaves of this region, just as Dr. Erland Lorenzen did the same for the region of Thüringer Wald, Erz- and Riesengebirge. Attempts made to build-up a wave-forecast generally available for glider-pilots, to organize and

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[a] www.mittelgebirgsleewelle.de/wredei.htm

document waveflights covering extended needs were severly hampered by expensive and slow communication methods. That’s why these early activities faltered during the following years.

The “Mittelgebirgswellen”-project in general

Towards the end of the eighties of the 20th century, all of these conditions had changed: a united German state existed; new materials for gliders were available; information exchange by email was fast and cheap, and the Internet provided an easily accessible platform for the publication of data. During the mid-nineties, www.mittelgebirgsleewelle.de developed into a forum for leewave-information documentation and information exchange for glider-pilots and - nothing but hope at the time - for scientists. The aim was (and is) to provide glider-pilots with information on where they could fly waves under which circumstances, and to gather information as parts of a puzzle for a leewave-climatology of the lower mountains in Germany. All of this remained on a strictly volunteer basis.

The most important contribution to the success of this initiative is the leewave-forecast by Dr. Erland Lorenzen, a free publication written for the single purpose of lower mountain wave-flying. The information is distributed to more than 400 recipients by mail, by Wolfgang Lieder, member of Aschersleben/Harz gliding.club, as a seven-days-a-week volunteer service.

For self-briefing-purposes the Deutscher Wetterdienst (DWD) provides specific information in form of its professional product PC_Met [b], which is not available free of charge. Beside the standard portfolio of tools for synoptic forecast there are specifics as predicted temps and development of scorer-parameter over altitude for diverse locations of the wave-area. The new DWD-tool “Sky-VieW – LMK” provides stunning options for wave-forecasts. In a high resolution- computer model, up- and downdraft-areas of the atmosphere are calculated and depicted in PC_Met-charts. Especially wavy flow of airmass is represented in an impressive way. Several comparative studies of forecast-charts and satellite-photos which are assigned from a temporal point of view demonstrate that the new routine is already working reliably.

On the other hand the documentation of wave-observation- and -flight-reports is intended to support the planning of flights. Up to now, reports on more than 500 wave-events have been published. The reports are sent to Joerg Dummann, Bad Gandersheim glider-club/Leinebergland by mail; he then passes them on to the same pool of recipients as the forecast is distributed to. The information is also permanently and in more detail published at www.mittelgebirgsleewelle.de also.

Outstandung events are the first flights initially using the smooth waves of the hilly environment of the Klix-Airfeld (near Dresden) towards the strong waves of the Riesengebirge, made by Jürgen Dittmar. He set out on this previously unimaginable adventure motivated only by means of theory and visions by Karl-Heinz Dannhauer, Leipzig-Oschatz gliding-club, in the www.mittelgebirgsleewelle.de information exchange [c]. Also worth highlighting is a flight to 7.200m MSL in the lee of the Harz-mountains by Carsten Lindemann and Bernd Goretzki [d], and a 300km FAI-triangle (started in Hofgeismar near Kassel) by Wolfgang Stoepel, only flown in waves above cumulus clouds [e].

Since the year 2000, meetings of the www.mittelgebirgsleewelle.de-community have taken place once a year at different locations, every second year as guest of the "School_Lab" - an institution of the "Deutsches Zentrum für Luft- und Raumfahrt e.V." in Göttingen. Glider pilots are report on their experiences and also lectures are held – during the early years by meteorologists Carsten Lindemann and Dr. Erland Lorenzen; and later on by Hermann Trimmel and René Heise. Fortunately, the group was able to establish contact with Prof. Dieter Etling, Professor for Theoretic Meteorology at "Institut für Meteorologie und Klimatologie" of the Leibniz-University Hannover, who contributes regularly

Regularly articles are published by aeronautic sports magazines reporting on the meetings and outstanding wave-flights.

It should be noted, that the entire organization is a decentral, self-organized network of contributors, with only a permanent crystallization point.

Methods, aims and obstacles

Most of the activities are directly or indirectly determined by the character and circumstances of practical flying. It is a simple but nevertheless a ruling fact that the number and distribution of wave-flight-reports depends on the intensity of gliding-activities in different areas and altitudes. The neighborhood of airfields is a preferred location for leewave-flights, due to the higher density of flight-activities, just as ridge-running-routes are. Areas with restricted airspace will not be locations of intense wave-flying. The current lack of wave-flights in the Suentel-Deister-System is due to restricted airspace in the neighbourhood of the Hannover-Langenhagen-Airport, while the usage of SW-Waves of the unrestricted Hasselberg-area is extremely frequent because of its situation near the SW-ridgelift-providing Wesergebirge. Flights exceeding altitudes of 10.000ft MSL are generally rare because of the necessity of air traffic clearances. Areas temporarily dedicated to high-altitude-soaring-flights, installed NE of the Harz-Mountains, the Hoher Meissner and the Thueringer Wald raise the number of wave-flights exceeding 3.000m MSL.

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[b] www.flugwetter.de

[c] www.mittelgebirgsleewelle.de/treffen04/khda/khda04.htm

[d] www.mittelgebirgsleewelle.de/hz301000.htm

[e] www.mittelgebirgsleewelle.de/ul160400.htm

There also will be some local self-reinforcement between reporting and flying, just as the influences of intense public relation activities concerning wave-flying practiced at some airfields is a given fact.

The reports show quite different stages of elaboration, depending on the individual intensity of interest and the capabilities of each reporter. Referring to the club-dominated structure of gliding-activities this is accepted, as this reflects the attitude of inviting anyone to contribute. A questionnaire has been developed to simplify and standardize the gathering of information. In nearly every case IGC-Files are of good use. Many photos are very instructive and even seem to be suitable for use in textbooks. Many of them are also simply beautiful.

The initial idea of an accompanying documentation of synoptic and atmospheric conditions has been given up, as it is too much work, and plenty of Internet-sources are available.

Continuity of reporting activities is also supported by a strong social component, as there is an active exchange of personal experiences within the gliding-community of northern Germany. A momentum, which played an important role also during the implementation of the activities.

The expectations of many glider-pilots regarding the exact cartographical depiction of leewave-positions are very high. The idea that a leewave may always be assigned directly to a specific mountain is very dominant. In spite of the fact that this is correct for single, outstanding elevations, the situation for the hills and ridges of the “Northern Germany Wave-flight Centre” seem to be much more complicated. It must be taken into account that small deviations in the atmospheric starting or persisting conditions of leewave-situations may generate different shaping of spacious wave-systems, consisting of interacting sub-systems. This is implicated by the fact that most of the leewave-observations have almost the character of singularities at many locations up to now (see fig. 3).

From 291 events / 588 flights at 59 locations in toto there are 97/126 distributed to 49 locations which can be seen as sparsely documented, 7 locations with 87/130 are better and 3 locations with 107/332 relatively well documented.

It is evident that superposing-effects in vertically oscillating flows and variations of the horizontal flow near the ground triggered by orography (confluences and difluences) will raise the complexity of the overall-system-behavior in a wide range. Over that it is difficult to close orographically induced waves off undulations triggered by other processes, as there are thermal activities, frontal collisions of airmass , shear-waves and similar trigger mechanisms. On 28 October 1989 obviously front-related, traveling waves enabled flights up to 5.000m MSL altitude by several gliders near the Bad Gandersheim airfield [f]. Even the best-documented waves, those of the Harz-mountains, show an unexpected complexity, which require extended experience to use them in a well-directed way. In this context the expectations to build up a catalogue of spatially clearly reproducible leewave-occurrences need to be curbed.

In 2007, first steps were made to gather more detailed meteorological information during the wave-flights. Up to now two gliders have been equipped with GPS-Data-Loggers. They have several digital and analogue ports available (see fig. 4).

At the moment temperature-, static pressure-, g-acceleration-data directly assigned to GPS-data-sets and time are acquired. Fortunately the logger is a product of a radio amateur volunteer work by Karsten Hansky and Dirk Langenbach [g]. The logger kit costs around 100,-- Eur. To complete the system a GPS-receiver (50,-- EUR) and a MMC/SD-Card (10,-- EUR) are needed.

There is still a lot of work to do for calibration and the development of IT-tools for evaluation purposes.

Observations, evaluations, questions, suggestions

Statistical evaluation of the whole data stock by depicting the chronological occurrence of waves over the course of a year reveals that they are mainly generated in autumn, winter and spring (see fig. 5a and 5b). Waves in (north-) easterly flows seem to reach a maximum in April and October.. These are less common than waves in (south-) westerly flows and generally do not propagate up to extended heights as those do.

The generation of leewaves is complex, and especially in case of lower mountains as triggering obstacles, a very sensitive process. So it is not surprising that practical experience sometimes shows deviations from theory or even totally new aspects, which seem worth investigating. These events offer thrilling opportunities to develop or even expand our knowledge.

Leewaves at low wind-speeds

Leewave-events at negligible differences of static pressure between luv and lee areas of a mountain range, causing only little transport of air-mass over the ridge (in other words: low wind-speeds), are to be observed occasionally (for example Harz-wave on 09 Dec. 2000 [h].). Sometimes these are even combined with a non-increasing lapse rate of windspeed per altitude. Such cases are described by Carsten Lindemann in a paper for the annual meeting in Goettingen 2008[i]. Exemplarily analyzing the situations of 21 Nov. 2006 and 4 Feb. 2008 at the Riesengebirge such a situation is documented using aerological data from Prague (luv) and Wroclav (lee). At 4 Feb. 2008, the Prague-1200Temp reports a wind-speed of only around 20 kts in the range from 2.000m to 3.500m, while the contemporaneous Wroclav-temp shows this from 2.500-5.000m. Nevertheless the Riesengebirge-Wave, which was

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[f] www.mittelgebirgsleewelle.de/gn281089.htm

[g] http://www.mydarc.de/dl3hrt

[h] www.mittelgebirgsleewelle.de/hz091200.htm

[i] www.mittelgebirgsleewelle.de/Treffen08/cli/cli.htm

absolutely unpredictable by means of Lester-Harrison-nomogram, was so strong that Milos Pajr (see flight-documentation on OnlineContest-website [j]) succeeded in reaching 6000 m while encountering climb-rates of more than 3 m/s. And he was even able to soar 721 km into the distance. It is still discussed whether the advection of an already oscillating air-mass could trigger such effects or not.

Leewaves and temporary lability

Spatial coincidence of shower- and leewave-activity only scarcely separated chronologically have been observed on 21.11.06 for the Isergebirge-, Eulengebirge-, Riesengebirge-Waves [k] and on 17.10.07 for the Vogler-wave-system [l] in the Weserbergland. The Vogler-wave regenerated rapidly after the throughpass of a shower. The base of a cumuliform cloud was observed being transformed into a lenticular shape.

"Limousine-rocking"

In some cases pilots noticed very small rhythmical vertical displacements of the plane occurring while wave-flying. These disturbances are some kind of smooth rocking or pitching. The effect cannot be seen while observing the horizon, it only can be felt. The frequency is around 1 sec. Supposing the glider's airspeed is around 80 km/h the horizontal extension of the turbulence can be estimated between 20m and 25m.

Klaus Bothe (Goslar/Vienenburg gliding-club/Harz), an experienced wave-pilot, experienced this phenomenon while falling out of the wave at the leeside. Most pilots encounter it while topping off the wave with decreasing climb-rates [m].

C.E. Wallington provides the following explanation [1] : Turbulence in a vertical shear-layer will set in when shear-forces have grown to a critical value. This turbulence will then lead to a reduction of the originating shear-forces (as shown in Fig. 6a) – in case there is no other process preventing this.
Such a special situation is given in a wave-system when the amplitude declines abruptly with every unit of increasing altitude (see fig. 6b).

In consequence of this constellation, augmenting shear in the crest of the wave will occur. This will cause turbulence there, which disappears leewards (see fig. 6c).

It might be an interesting challenge to investigate whether this turbulence in such a small scale can be wavelike – as the reaction of the plane implies – or not. And, in case of verification of this idea, to research, whether the effect is always directly bent to an inversion layer.

A vivid hint is probably provided by the phenomenon that billows are commonly seen in association with wave clouds. In their simplest form, billows appear as cloudbands moving through the wave pattern, although the wave cloud as a whole remains quasi-stationary [2].

Contemporarily wave triggering ridges of different heights

The height of an inversion above a ridge is thought to be small to be able to trigger leewaves. This condition becomes relevant especially for the question whether leewaves can originate simultaneously from ridges of considerably different heights or not. Such a situation for example is given by the hills of the Weserbergland (300m) and the Harz (main plateau 500 m, Brocken 1.140m) or by the elevations of the Lausitzer Bergland (500 m) and those of the Riesengebirge (1.500 m).

It was reported by Juergen Dittmar (Aeroteam Klix/near Lausitzer Bergland) that on 29 Oct. 2007 it was possible to contemporarily fly waves in the region of Lausitzer Bergland and of Riesengebirge [n] (see fig. 7). In generalized form the situation is shown in figure 8.

To explain this fact several ideas exist:

- there may possibly be two different airmasses at the same time over Lausitzer Bergland and Riesengebirge each with an inversion at proper height. They would have to differ by 1.000 m over a distance of 80 km.
- there may perhaps be two mechanisms to trigger oscillations of a solitary inversion layer with respect to the vertical distance to the ridge of it, one for small distances and one for large distances.
- there might be a homogeneous airmass with two inversions at different heights, which each matches the wave-criteria for a 500 m and a 1.500m ridge.
- it is not quantitatively substantiated to which extent leewaves are bound to sharply defined discontinuities in vertical stability. Perhaps smooth transitions of this parameter offer the conditions for the genesis of waves in a wide- spanning stable layer as well.

In case of Oct. 29,07, it seems plausible to suspect the option before-last-mentioned above: the luv-situated Prague-1200temp shows two inversions. One in the range from 600 m to 800 m and another one between 1.950 m and 2.100 m (see fig. 9). The 300km windwards situated 1200temp of Muenchen-Oberschleissheim shows a comparable structure, as does the Prostejov 300km to the southeast. So we can resume that both inversions seem to exist in a synoptic scale.

"Mountain inversions" assumed by Prof. Walter Georgii

Nevertheless, the first approach may also need to be considered: Georgii describes the phenomenon of orographically-induced "mountain-inversions" [3]. Such inversions are assumed to develop while a stable layered airmass passes over a mountain. Induced by surface-friction

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[j] www.onlinecontest.org/olc-2.0/gliding/flightinfo.html?flightId=-434888158

[k] www.mittelgebirgsleewelle.de/2006/061121/kl/kl211106.htm

[l] www.mittelgebirgsleewelle.de/2007/071017/it/it171007.htm

[m] www.mittelgebirgsleewelle.de/scherwel.htm

[n] www.mittelgebirgsleewelle.de/2007/071029/kl/kl291007.htm
www.mittelgebirgsleewelle.de/Treffen08/jdi/jdi.htm

forces, it will be mixed up turbulently until adiabatic stratification prevails up to an altitude of about 250 to 500m over the ridge, in case of lower mountains, in detail referring to mountain-height, aerial stratification and windspeed. It would be interesting to keep the phenomenon of "self-generating inversions" and their suspected, regionally limited role for the development of leewaves in consideration.

Wave–triggering at sub-critical flow

But also the second possibility must be taken into account at least in a purely theoretical manner. Dr. Joachim Kuettner first postulated in his doctoral thesis [4] a trigger-mechanism for waves generated by an atmospheric interface situated in a "large distance" vertically above a ridge. This is roughly described by the mechanism of the "hydraulic paradox". Initiated by a specific vertical distance of the inversion from the ridge in combination with other factors (as the luv-lee-pressure-difference, stability of the ridge-overcoming air-mass) a minimization of the vertical flow-square occurs, causing an acceleration of the flow (law of continuity) up to its critical speed. This causes a reduction of static pressure (law of Bernoulli) which generates a locally persistent deflection downwards of the inversion-layer. It also would be interesting to keep in mind this hypothetical way of orographically induced waves, which is up to now taken into account in scientific publications (for example Baines [5]). This hypothesis explains smooth waves guided by high-altitude inversions with their primary troughs directly above the ridge-line (see fig. 11).

Additionally, other possible flow-regimes such as partially (see fig. 15) or totally supercritical flows have to be kept in mind while observing nature during wave-flights.

Foehn-effects at the Harz-mountains

Comparing temperature-data of the climatological stations Goettingen (SW-luv, DWD), Wernigerode (narrow SW-lee, private) and Magdeburg (distant SW-Lee, DWD), Prof. Karl-Heinz Dannhauer found a significant warming of more than 9°C for the Wernigerode-station relative to the other stations for the 26.10.06 at 7:00 MEZ (see fig. 12a). The presumption of a foehn-effect being the reason for this is supported by the fact that static pressure at this time reached a minimum value at Wernigerode (see fig. 12), while windspeed shows an inverted development.

Popular science

In some astonishing cases, popular science has failed to fill the gap between up to one-hundred-year-old research results and pilots' knowledge up to now. Present-day vivid presentations of leewave kinematics also contain several fundamental implausibilities. This causes extensive need for clarification.

The foehn-principle

Most representations of the foehn-principle only refer to the warming-effect by a thermo-dynamical kind of view and beyond that overemphasize a side-effect, while totally neglecting fundamental insights originating from the work of Hann [6] (quoted according to Steinacker [7]). Hydro-dynamic aspects, forcing the descending downslope flow mainly as postulated in 1953 by Dr. Hermann Schweitzer [8] are not taken into account at all.

The documented Harz-foehn-event - as many others – can not be explained by the foehn-theory published in textbooks for flight-meteorology or other sources of popular science, as it was not accompanied by cloud cover and precipitation upwind ("Steigungsregen"). The last-mentioned is an essential factor of the widespread hypothesis to explain the warming of the leeside as shown in figure 13.

So it is evident, that there is a need to reflect this kind of view and thereby take into account the historical development of the idea. The Austrian meteorologist Hann postulated this thermodynamic foehn theory already in 1866, which he termed "Swiss foehn". But he also emphasized that precipitation on the windward side is not a necessary condition for foehn-effects and provided an alternative explanation for the warming of the leeside, titled "Austrian foehn". The general precondition for foehn in this view is a stable stratification of the windward airmass in combination with a descent of air at dry-adiabatic lapse rates on the leeside (see fig. 14).

In spite of the fact, that the "Austrian foehn"-model minimizes discrepancies between nature and theory, this concept did not enter the bulk of the textbooks, and even in Hann's own textbook it has been replaced by the usual, questionable version in a major revision after his death (Hann-Suering [9] quoted according to Seibert [10]).

The "Swiss foehn"-model, which is to be found in almost every meteorological textbook and is taught in school up to now, is revealed as a special case in the light of an only qualitative examination with no significance for the general explanation of the phenomenon "foehn". An adequate quantitative examination of the postulated effect shows that it is too small to generate the observed leeside-warming [7, 10].

So it seems to be overdue that publications at the level of popular science should be revised, so as to include state-of-the-art explanations of the foehn-mechanisms.

Beyond that, already in 1943 von Ficker (and de Rudder) [11] pointed out that these purely thermodynamically oriented reflections needed supplementing by consideration of dynamic aspects of airmass movement. In spite of the fact that - beginning with the lecture by Schweitzer at "Gebirgsmeteorologentagung" 1962 at Obergurgl - nowadays such mechanisms are indispensable parts of foehn-theory, they were not included in popular scientific literature.

The current scientific explanation of the hydrodynamic mechanism forcing the air to descend leewards logically originates from the current thermodynamic foehn-theory, which postulating the existence of a stable atmosphere in the luv. Under natural conditions, stability is not evenly distributed. Discontinuities of stability may often observed in form of overlaying or intermitting airmasses of higher temperature.

Depending on the combination of the altitude of the inversion–layer above the mountain-crestline and the size of the luv-/lee-difference in static pressure, the resulting narrow section more or less determines the pressure balance between luv and lee beneath the inversion. If its maximum transport capacity is reached, a depression of static pressure is generated directly leewards of the ridge. So in this area the atmospheric interface is forced to dent downwards, depending on how significantly pressure has been lowered there. Beginning with a shallow trough parallel to the ridge, developing in a self-amplifying manner to a climax state in which the inversion layer is almost attached to the lee-slopes. The minimizing of the square of the flow-channel generates severe downslope-windstorms (see fig. 15). Airmasses of the inversion or from above, additionally warmed by adiabatic processes, may touch the valley floor. An event, which is experienced as break-through of the foehn. The windstorms calm down in downwind-regions where the orographically-caused flow channel widens up again.

Further undulations of the airmass, triggered by different stages of this process, can establish a leewave system downwind of the ridgeline. Various conditions influencing the process of mainly vertical or horizontal propagation of these waves are generally known (but not discussed here). The climax state of the system is reached by maximization the luv-/lee-static-pressure difference and by (self-generated) minimizing the square of the lee-slope-attached flow-channel and will occur as an unsteady return to sub-critical flow with no subsequent waves (hydraulic jump).

A proposal for a modified didactical approach for the understanding of aerial wave-kinematics

From a phenomenological point of view it seems to be overdue to investigate whether the comprehensive understanding of wave motion carried by atmospheric temperature inversions can be explained only in a hydrostatic context as practiced up to now. The historical evolution of foehn-theory may serve as an example for the necessity not to neglect a hydrodynamic point of view. So another topical question is: may didactic reduction disregard kinetic forces, which are obviously causing and maintaining aerial wave motion?

This question has already been answered in scientific primary literature, which established that the all-over energy of atmospheric gravity waves is combined by varying proportions of kinetic and potential forms of energy [12, 13]

But in popular science the kinematics of aerial gravity-waves, including leewaves, are generally described as an overshooting antagonism between buoyancy and gravity forces within a stable airmass. Closer examination reveals that this model describes nothing but an oscillating “airparcel” which is transferred with the speed of the airmass (windspeed) relative to the ground (see.fig 16).

It is not a wave motion that is described in this manner and by far not an explanation of a “standing wave”, which leewaves are supposed to be. The model suffers from the lack of a process, which can cause the horizontal propagation of the vertical oscillation. To establish a standing wave, the propagation speed of the wave has to be equal to the groundspeed of the airmass, but working in the opposite direction. The propagation of transversal waves – the wave-type discussed so far – takes place at right angles to to the direction of oscillation. The conduct of energy in this direction is only possible by friction processes. As friction plays a negligible role in case of liquids und gases, transversal waves cannot occur in these mediums (see fig. 17 left side). Only solid state materials have the ability to allow the propagation of transversal waves, because friction is strong enough (see fig 17 right side).

But gravity waves on water surfaces seem to prove that this statement is wrong: because it is a common phenomenon that vertical oscillations spread out after they have been triggered by a stone’s plunging in (see fig. 18) or wind blowing over a pond (see fig. 19).

But the phenomenological impression is misleading. In case of water-surface-waves it is known, that they are a mixture of transversal and longitudinal wave components. The last-mentioned waves are propagating in the direction of their oscillation (see fig. 20). The vertical (transversal) component is driven by buoyancy and gravity, the horizontal (longitudinal) component by compression and dilation. Vertically, variations of potential energy occur, horizontally, the amount kinetic energy varies. Longitudinal waves are able to propagate in any medium. In case of water-gravity-waves both processes are coupled in a manner that is comparable with the energetic behaviour of a swing: potential energy is transformed to kinetic energy and vice versa [12]. Any lifting of a “watercolumn” higher than the surface immediately encounters a compensating lateral expansion (and vice versa) – the idealized situation shown in figure 17 left side can never occur. Or in other words: any amount of potential energy which is gained will be changed to kinetic energy until a certain steady state between both energy-forms is achieved (and vice versa). The wavetype focussed here consists of variations around this steady state of these two different energyforms. The troughs are dominated by kinetic energy, the crests by potential energy. This wavetype is known as “Rayleigh”-wave (see fig. 21). Their propagation is driven by the longitudinal component of wavemotion. The dual-character of this wavetype is the reason for the orbital track of “water-parcels” or tracer-particles, which is seen when a wave passes by: when the crest of a wave approaches, a tracer-particle in the water-mass swings nearly horizontally towards it, while it passes, the tracer is lifted up and follows the wave again mainly horizontally to the opposite direction as before and then descends while beginning to swing back approaching the following crest [o](Footnote: Internet-Link).

Following the question which processes might cause the propagation of a leewave against the wind – initiating the "standing-wave-effect" - it is plausible to suggest that Rayleigh-waves occur in gases in a comparable way, not guided by the surface of the medium but by discontinuities in the vertical loss of density, interfaces which are regular phenomena in the Earth's atmosphere in the form of inversion-layers.

And simple observation of nature seems to support this assumption in a phenomenological way. A cumulus penetrating an inversion-layer marked by a stratus, causes the same wave-pattern in the cloud-layer as is generated by a stone thrown into a pond (see figs. 22 and 18).

The same habitus may be concluded when comparing wind-driven water-gravity waves and inversion-guided shear-waves, originating from difference in windspeed of the airmasses above and below the aerial interface (see fig. 23). The genesis of aerial shear-waves is bound to the input of kinetic energy to the discontinuity in density by friction-effects. In spite of the fact that they behave phenomenologically like pure transversal waves, it is obvious that there must be a mechanism that is changing kinetic energy to a transversal component of wave-motion.

If shear-forces have reached a critical value energy is conducted to the underlaying airmass via friction-processes. This redistribution of energy will then lead to a reduction of the shear-forces (Wallington, as shown in figure 6a). This effect means that only a limited area of the lower layer is affected by accelerating forces windwards. This in turn leads to compression (pressure increasing) effects towards the leeside of the airmass influenced by this input of energy (see fig. 20). In this way kinetic energy is converted to potential energy in form of an upgrowing wavecrest driven by increased static pressure in this area (see fig. 21). Due to its own characteristics, this triggering process is repeated rhythmically, harmonizing with the specific air-mass-induced swing-like game of converting both forms of energy into each other, finally building "ordered turbulence" in the form of a wavetrain.

The important question raised is whether all aerial gravity waves underlay both, variations in potential energy and kinetic energy or not. The first in form of the antagonists' buoyancy / gravity is generally accepted; the second is mentioned in some textbooks [12] without offering the any comprehensible models for understanding. Such can be thought as an antagonism of compression / dilation.

Other aerial gravity waves, generated by vertical or horizontal energy-pulses (such as fronts, thunderstorms, low-level-jets...) are traveling through the Earth's atmosphere in case of stable layering, some bound to discontinuities of it. By relating to the passages of such undular bores or solitary waves, like morning-glory-waves in Australia, it is generally reported that the area of the wavecrests are marked by a significant increase of static pressure near the ground in the order of 1 hPa. This obviously takes place without changes in the vertical extension of the column of air thought to be above the measuring instrument.

The wind field near the ground, in cases of passing waves, shows a behavior as if fluctuations of kinetic energy occur in a ways which are similar to those of waterwaves.

While undular bores were traveling over Iowa on Oct. 3, 2007 people in Des Moines actually felt this back-and-forth breeze as the waves passed overhead. "Flags few one way during the crest of the wave and swung around 180° to fly in the opposite direction during the trough" [p]

The experience of crossing a morning glory wave by plane is described as follows: "The leading updraft and trailing down-draughts are intense. Solitary wave disturbances may exceed 20 knots and the horizontal wind component near the surface can vary by more than 30 knots during the passage of the wave. Aircraft which encounter a solitary wave from the front (…) will rise above the intended flight path under the influence of the leading up-draught and increasing headwinds. The natural reaction of a pilot at this point is to attempt to return to the normal glide path, but this action, when combined with the sudden loss of headwind and increasing downdraughts behind the wave can leave the aircraft perilously close to ground, well short of the runway threshold. The situation faced by a pilot may be more complicated when the aircraft encounters more than one solitary wave while on final approach. In this case, the winds acting on the aircraft may give the appearance of alternating head and tail wind components, thus compounding the problem of aircraft control." [q].

Increasing air-pressure is obviously bound to the confluence of airmass caused by longitudinal components of wave motion.

Referring again to aerial shear-waves Georgii wrote in 1927 [3]: "The reason for the generation of waves is the discontinuity in density caused by changes in temperature and the commonly occurring discontinuity of wind along the interface. The wave-motion of air within this layer is the same as the wave-motion of water. Each "air-particle" swings along elliptic tracks... The..." (flow) "...which generates from the combination of orbital movement of single "air-particles"

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[o] Instructive animations are to be found at: http://physics.nad.ru/Physics/English/wav_txt.htm

[p] http://science.nasa.gov/headlines/y2007/11oct_undularbore.htm?list1043252

[q] http://www.dropbears.com/brough/Aopa.htm

within a progressing wave...” (is) “...shown in figure (...).” (see fig. 24).

Supposing the same mechanics determine leewave-systems in a similar way, the triggering of a leewave happens by both factors: the vertical displacement of airmass near the leeslope as well as its acceleration in this limited region. Downwind the speed-up-effects do not occur further on (as described in the context of the foehn-genesis) which effects a compression zone marked by increased static pressure combined with lowered windspeeds near the ground (see figs. 15 and 25). This combination indicates the postulated conversion of kinetic energy to potential energy, which is here supposed to be the motor for the development of the first wavecrest. It is a self-ruling effect that this transition-area finds its position where the speed of longitudinal wave-propagation is equal to the inversed speed of airmass transport.

Under certain conditions this process is repeated rhythmically (see fig. 26). Maximized input of energy to this system leads to its climax-state which is no longer a rhythmical, fluent process but an abrupt, explosion-like conversion from kinetic to potential energy, which is regarded to be an analogon to a hydraulic jump.

The region which here is supposed to be a location of energy-transversion is generally called “rotor”. Current sketches of simplified longitudinal sections of a leewave-system almost always show the flow in the rotor region as a closed vortex with a horizontal axis parallel to the ridge. This depiction implicates the rotor being some kind of a roll bearing of the wave-flow above and in this manner being a product of it.

Observation of nature reveals that this kind of flow is actually occurring under the crests of aerial gravity waves – but by far not in all wave-systems. Obviously not each rotor-cloud has the character of a roll-cloud, while rotor-flow near the ground not always appears in form of reversed flow. Over that, the appearance of rotor-clouds is impressively diverse. It stretches from small solitary scraps of cumulus-fractus-clouds over broad banks of cumulus clouds (see fig. 27) to gigantic vertical walls.

The question is raised as to whether the “roll-bearing”-model is able to correspondingly describe the diversity of appearance or if a more general kind of view identifying the rotor-region as a location of energy-transformation is more suitable for describing the wide-range-differing phenomena.

Future projects

There is already a considerable backlog of data-sets awaiting processing and evaluation, collected at numerous well-documented flights in the Hasselberg- and Vogler waves. It is intended to try out a more elaborated comparison of prevailing flight characteristics with observed meteorological conditions.

Beyond that, it is planned to retrieve information about the height, intensity and thickness of stable layers which allow the generation of gravity-waves by means of GPS-data-loggers.

In the context of endeavors to find out the lateral extension of foehn-effects of the Harz-mountains it is also taken into account to try to link up these measurements with data from terrestrial meteorological stations. The first steps preparing collaboration with a committed radio amateur group may provide the technical equipment for measuring and telecommunication purposes.

The usage of thermal waves by glider-pilots seems to be underrepresented compared to the number of obviously existing chances to do this, provided by suitable meteorological conditions. There is a need to start some kind of information campaign referring to this and the understanding of the phenomenon.

It is amazing to observe wide-ranging leewave-systems photographed by satellites in synoptical scale, which obviously are steadily in place. Even if this is a bit removed from practical flying purposes, it is nevertheless thrilling to find out about the causes of this phenomenon.

Starting in 2008, the verification or falsification of wave-forecasts provided by a computer model built up by Dr John W. Glendening [r] and implemented by Hendrik Hoeth for the northern Germany region [s] is planned.

All these activities are accompanied by a steady interest to document historical aspects of wave-flying in northern Germany and to try to document the evolution of ideas, hypotheses and theories in science related to the topic of atmospheric waves.

To spare some time for all this, it is intended to implement a content-management-system for the “Mittelgebirgswellen”-website, which will allow an upload of observation- and flight-reports by the pilots themselves – in spite of the fact that specific knowledge for this plan is lacking up to now.

Concluding remarks

Gliding has always been primarily the experience of nature. This statement is even valid for aeronautical activities, which seem to be dominated purely by sportive competition. In many cases gliding has triggered and influenced especially meteorological research, and in this way has been a link between a vivid encountering of natural phenomena, and explanatory science. In this context the offer of the present report to science is to make use of the possibilities for data acquiring the described gliding-initiative is providing.

But on the other hand this report also places a demand on science, to clear up the backlog of progressing specific knowledge which for many years obviously has not been given back in a form suitable for understanding, by those who could

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[r] www.drjack.info

[s] rasp.linta.de/NIEDERSACHSEN_WAVE

profit from it while handling the phenomena practically. It seems that OSTIV, as far as its constituting aims are concerned, may play an outstanding role in this desirable process.

Acknowledgments

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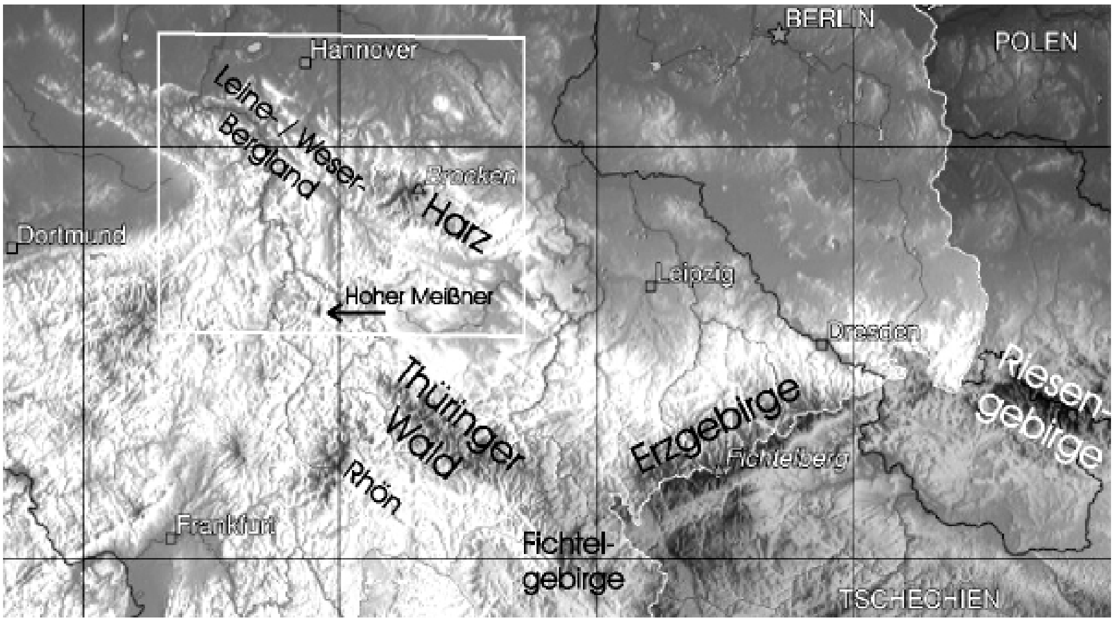


Figure 1 Wave area of the lower mountains of Northern Germany (the heartland is marked by a frame) [Source of chart: www.mygeo.info/landkarten_deutschland.html under GNU Free Documentation License].

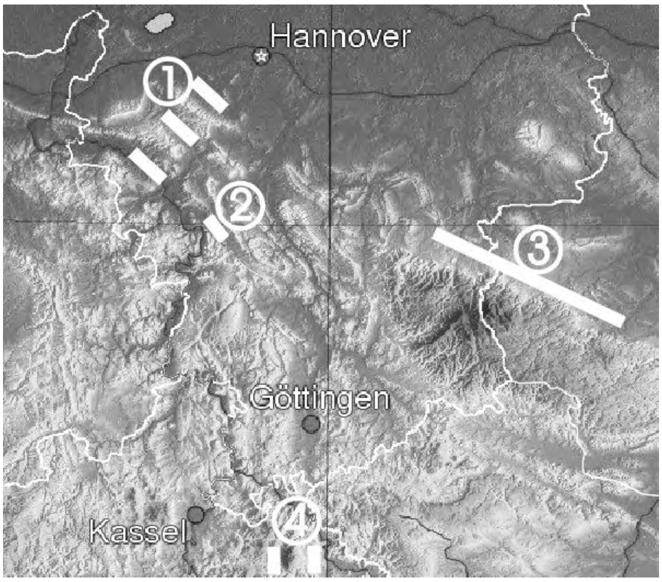


Figure 2 "Northern Germany Wave-flight Centre". Marked are the frequent SW-Waves of the Harz- (3) and the Vogler-Mountains (2), as well as those of the famous Hasselberg-Süntel-Deister-System (1) and the W-and E-Waves of the Hoher Meissner (4). [Source of chart: www.mygeo.info/landkarten_deutschland.html under GNU Free Documentation License]

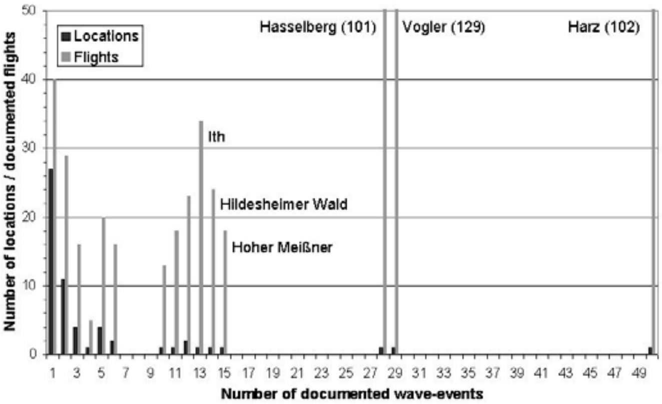


Figure 3 Distribution of wave-locations and documented flights over number of documented wave-events referred to the area defined in fig. 1/2

Figure 4 The GPS-data-logger MPL-3440 mounted in a SZD 24-4A Foka 4

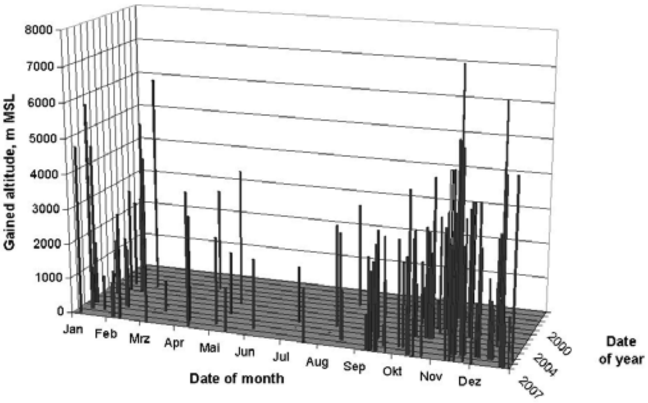


Figure 5a Chronological occurrence of maximum altitudes gained in course of leewave-flights in south-westerly flows (120°-299°) from1997 to 2007 put together after reports of the pilots

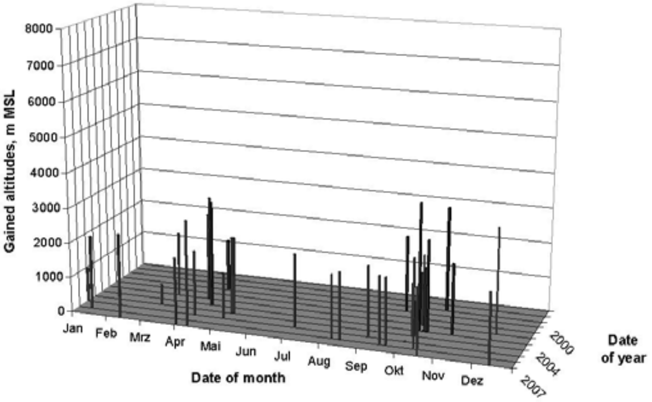


Figure 5b same for north-easterly flow (300°-119°)

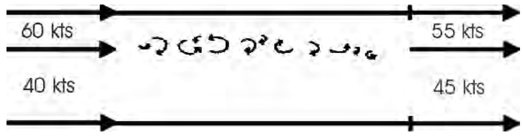


Figure 6a Reduction of shear-by turbulence [Source: Wallington [1] p.230]

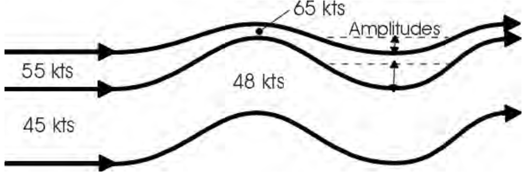


Figure 6b Augmenting shear in consequence of declining amplitudes with increasing altitude [Source: Wallington [1] p.230]

Figure 6c Turbulence in wave-crests caused by augmenting shear which is due to declining amplitudes with increasing altitude [Source: Wallington [1] p.230]

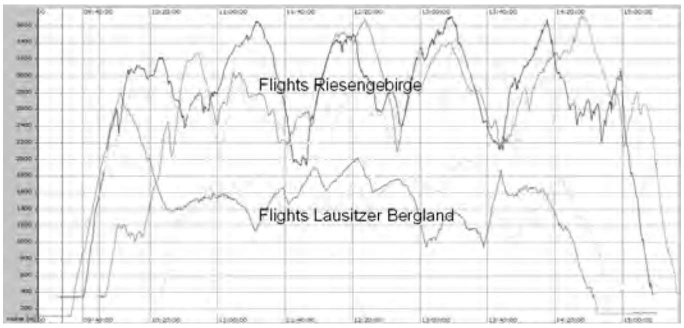


Figure 7 Comparison of altitudes gained in the course of wave-flights on 29.10.07 at Riesengebirge and Lausitzer Bergland [Source: Juergen Dittmar, www.mittelgebirgslee-welle.de/Treffen08/jdi/jdi.htm]

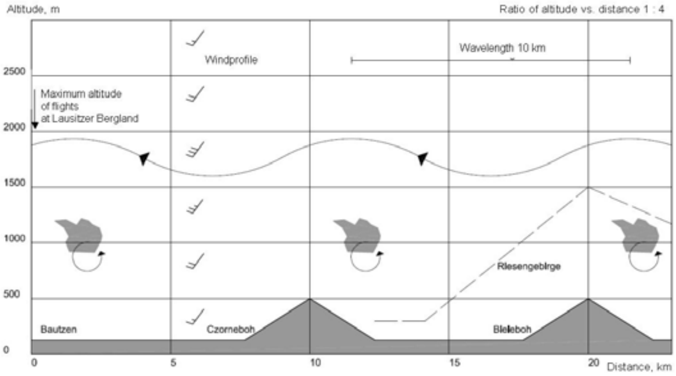
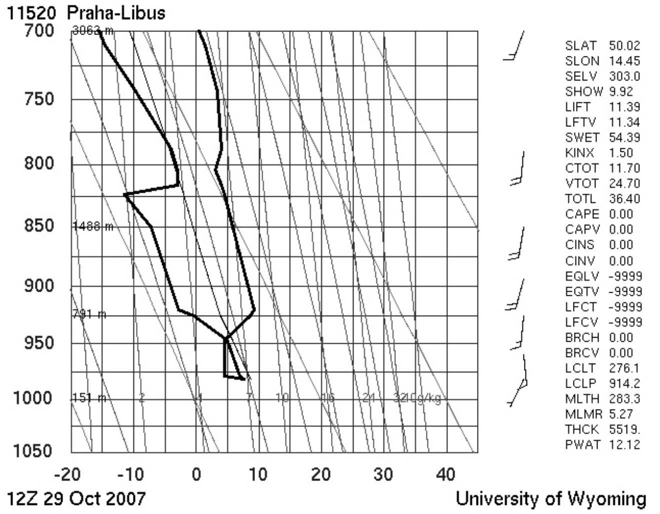


Figure 8 Vertical scheme 29.10.2007 [Source: Juergen Dittmar, www.mittelgebirgslee-welle.de/Treffen08/jdi/jdi.htm



SLAT	50.02
SLON	14.45
SELV	303.0
SHOW	9.92
LIFT	11.39
LFTV	11.34
SWET	54.39
KINX	1.50
CTOT	11.70
VTOT	24.70
TOTL	36.40
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LFCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	276.1
LCLP	914.2
MLTH	283.3
MLMR	5.27
THCK	5519.
PWAT	12.12

Figure 9 Temp Praha-Libus 29.10.07 12Z [Source: University of Wyoming, http://weather.uwyo.edu/upperair/europe.html]

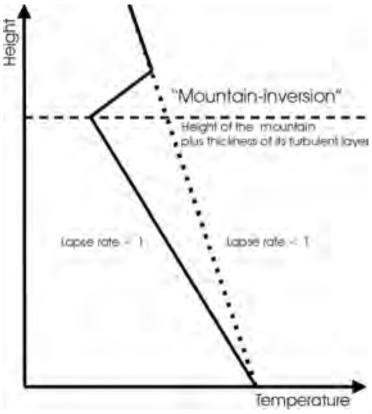


Figure 10 Mountain Inversion [Source: Georgii [3] p. 128]

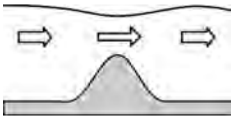


Figure 11 Hypothetical wave generation by "hydrodynamical paradox" in a subcritical flow [Source: Baines [5] p. 42, modified]

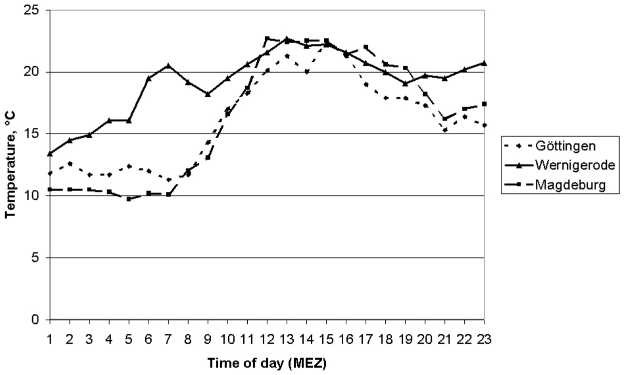


Figure 12a Development of temperatures on 26.10.06 along a luv-/lee-section across the Harz-mountains at comparable heights [Source: Prof. K.-H. Dannhauer, www.mittelgebirgs-leewelle.de/treffen07/khd/khd.htm]

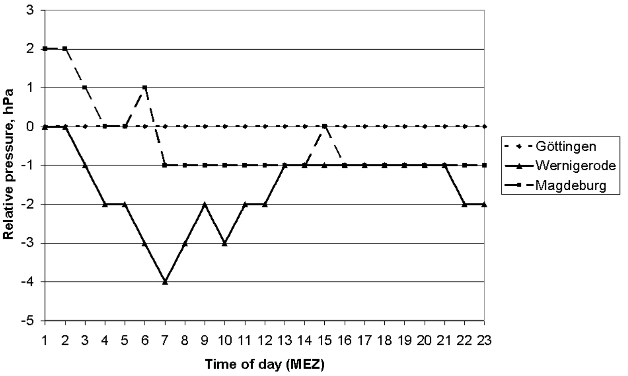


Figure 12b Same for relative static pressure (referred to luv-station Goettingen – in order to filter off synoptic influences) [Source: Sketch generated from Data provided by Prof. K.-H. Dannhauer]

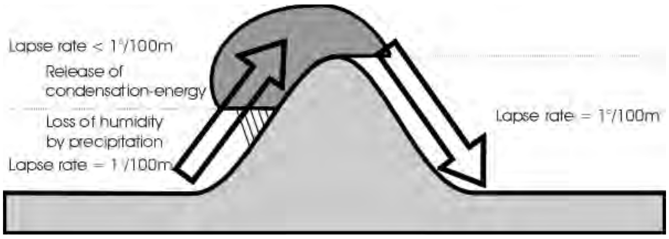


Figure 13 Classic thermodynamical foehn-principle or "Swiss-foehn" after Hann [6] quoted according to Steinacker [7], p.4]

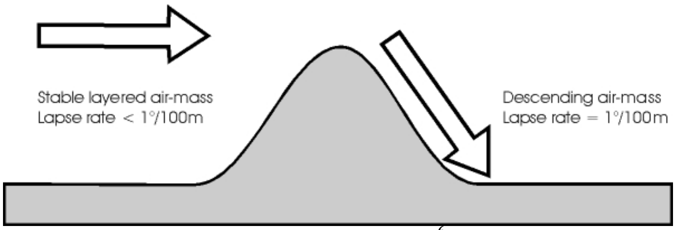


Figure 14 "Austrian foehn" after Hann [6] quoted according to Steinacker [7], p.4]

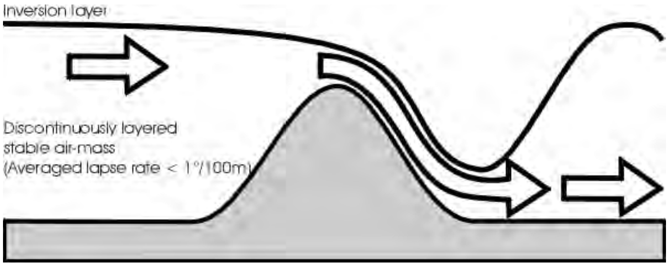


Figure 15 Foehn as partially supercritical flow [Source: Steinacker [7], p.5, modified]

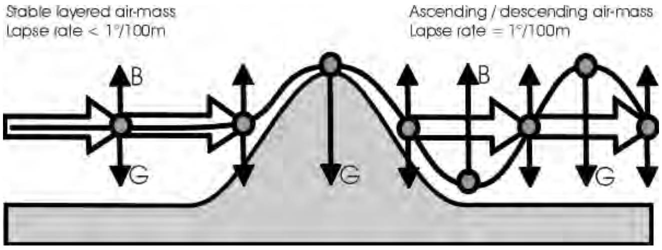


Figure 16 Oscillating „airparcel" horizontally driven by wind (B = Buoyancy / G = Gravity)

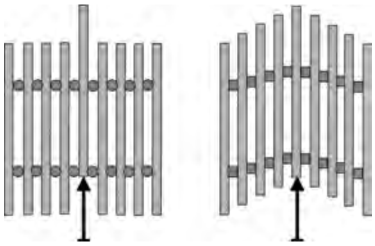


Figure 17 Lateral friction allows a propagation of a vertical pulse by transversal waves

Figure 18 Ringwave on watersurface

Figure 19 Wind generated waves on watersurface

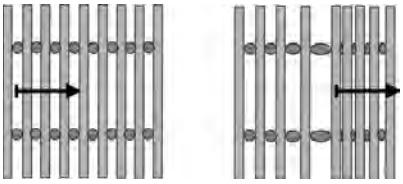


Figure 20 Lateral passing on of a horizontal pulse by compression and dilation allows a propagation of longitudinal waves

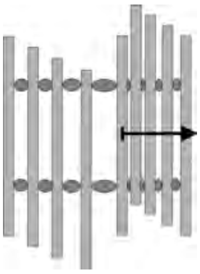


Figure 21 Sufficient vertical decrease of density / pressure allows of the propagation transversal/longitudinal-mixed Rayleigh-waves.

Figure 22 Ringwave on an aerial interface [Source free of rights: www.cepolina.com/freephoto/f/nature.water.clouds/cloud.hill.jpg]

Figure 23 Wind generated waves on an aerial interface

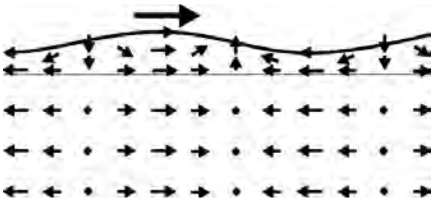


Figure 24 Flow of an aerial wavemotion [Source: Georgii [3] p.25]

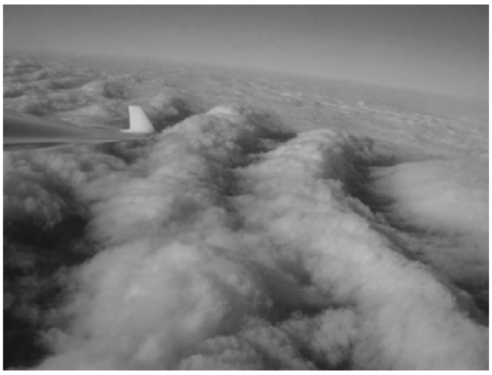


Figure 26 Wave-system of the Ith (Source: Andreas Gidde, gliding-club Hameln / Weserbergland) www.mittelgebirgs-leewelle.de/2006/061015/it/it061015.htm]

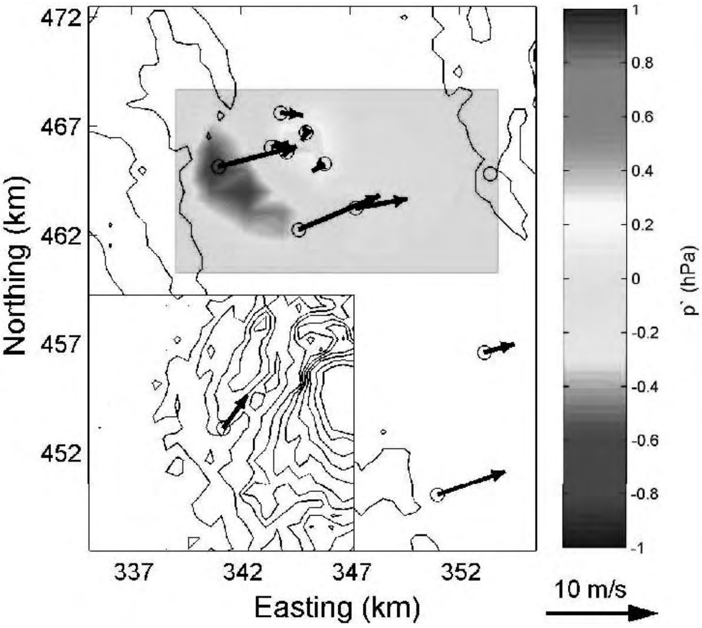


Figure 25 Variations of winds and differences from prevailing static pressure induced by a leewave-system. The dark shaded area symbolizes lowered pressure in the order of about 1 hPa accompanied by high windspeeds directly in the lee of the ridge, situated more leewards a smaller, light-colored area – especially the slightly darker centre of it - symbolizes raised pressure in the order of 0,3 hPa accompanied by weakened windspeeds with varying directions, the region of the rotor. [Source: Sheridan et al. [14] p.12]

Figure 27 Extended, flat rotor-clouds of an Acker-Bruchberg-Massiv / Harz wave-system [Source: Matthias Picht, gliding club Osterode / Harz] www.mittelgebirgsleewelle.de/031108/hz/hz081103.htm]