Gottfried Erich Rosenthal (1745-1813), a follower of Deluc in northern Germany

Geneva (372 m) seen from the Salève (1379 m)

Brocken (1141 m) seen from Wernigerode (240 m)

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Abstract

G. E. Rosenthal, a follower of Deluc in northern Germany

Gottfried Erich Rosenthal (1745–1813) was born and died at Nordhausen (now in Thuringia). As his ancestors, he became a Master–Baker after his studies at the local Gymnasium, where he excelled in mathematics. In 1779, after reading the 1772 treatise by Deluc, he became interested in meteorology, building and selling (even to Goethe) thermometers and “improved” barometers, and using them to measure elevations, notably of the near Brocken.

For the temperature correction of the barometer readings, he graduated his mercury thermometer (one is preserved at Lausanne) with four uncommon scales. In 1787, three years after finishing his monumental “Beyträge…”, where he described his instruments and his hypsometric measurements, he gave up meteorology, for unknown reasons.

How high are these mountains?

We'll see how it is possible to measure rather precisely the elevation of a mountain, between two stations, using two *clocks*, a pair of mercury *barometers*, as well as a pair of *thermometers* to correct the barometer readings and to take into account the temperature of the column of air between the two stations.

Summary:

A mysterious-looking mercury thermometer

Top:
Rosenthals Scalen
Beÿträge No. IV

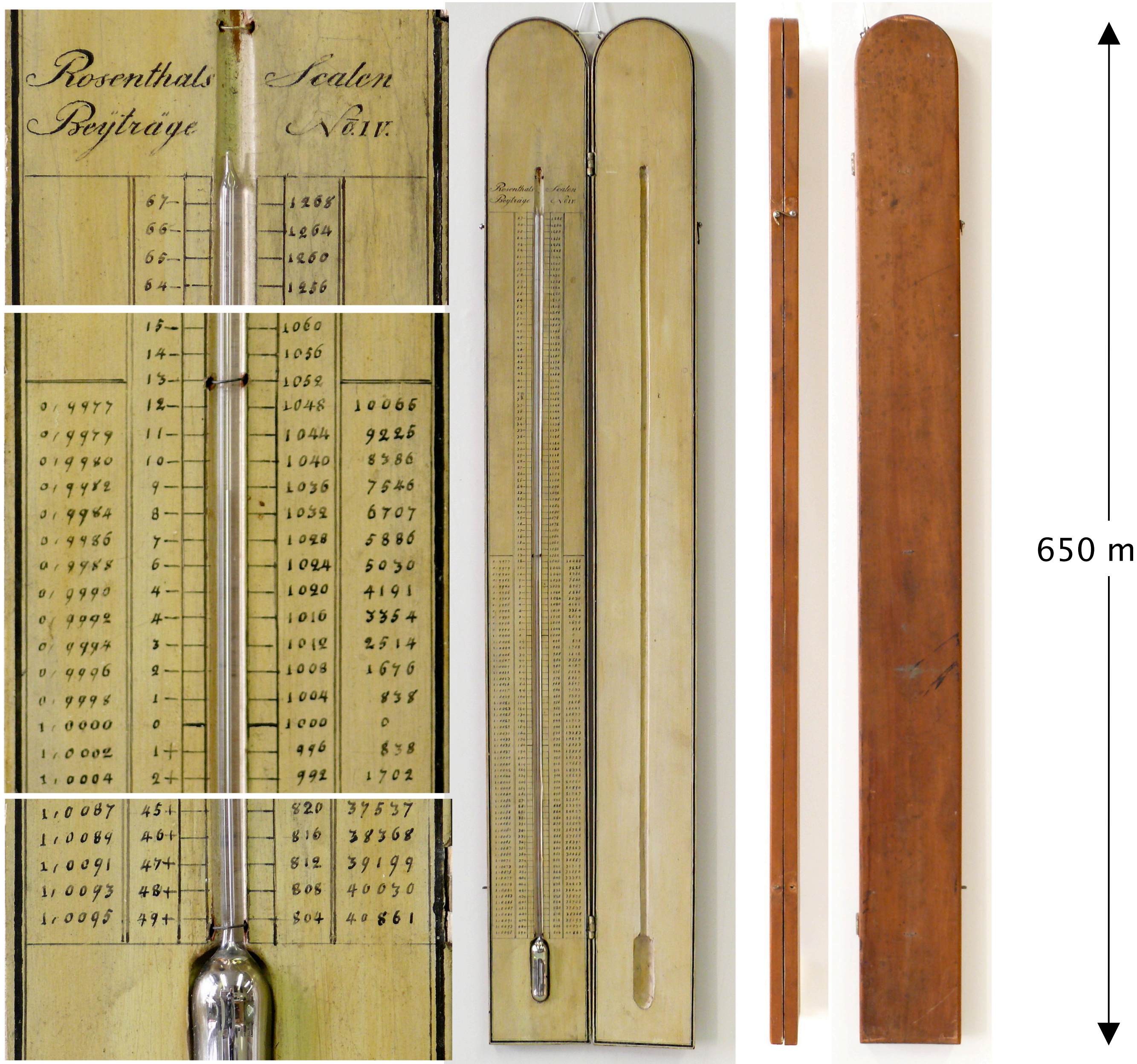
Hg tube too short?

Middle:
4 unknown scales

T_{ref} ?

1 – 0 – 1000 – 0 →

Bottom:
Hg bulb



UNIL – Musée de physique – Inv. 603.096

Gottfried Erich ROSENTHAL (1745–1813)

"Bergcommissar" in 1783

- Born and died at Nordhausen, Imperial Free City until 1807
- Studies at the local Gymnasium, gifted for mathematics
- Becomes a "Meister Bäcker", as his forebears since 1570 and later family members until 1923
- Prefers to study, becomes a land surveyor, publishes in 1772 a "Comparison of weights and measures used at Nordhausen and elsewhere"
- 1779–1787: Meteorological period, makes and sells barometers and thermometers From 1780, probably no more active as a baker
- 1788–1808: publishes a large number of (deservedly forgotten) litterary-scientific-technical works of encyclopedic character

ROSENTHAL's meteorological period (1779–1787)

Reads the book *Modifications de l'atmosphère* (Genève 1772) of Jean-André Deluc (Geneva 1727–England 1817), becomes interested in meteorology


Beyträge
zu der
Verfertigung, der wissenschaftlichen Kenntniß,
und dem Gebrauche
meteorologischer Werkzeuge.

Erster Band.

von
Gottfried Erich Rosenthal,
Bürger in Nordhausen,
er Churfürstl. Maynzischen Akademie nützlicher Wissenschaften zu Erfurt,
der Naturforschenden Gesellschaft in Halle ordentlichem, und der Gesell-
schaft Naturforschender Freunde in Berlin Ehren-Mitgliede.

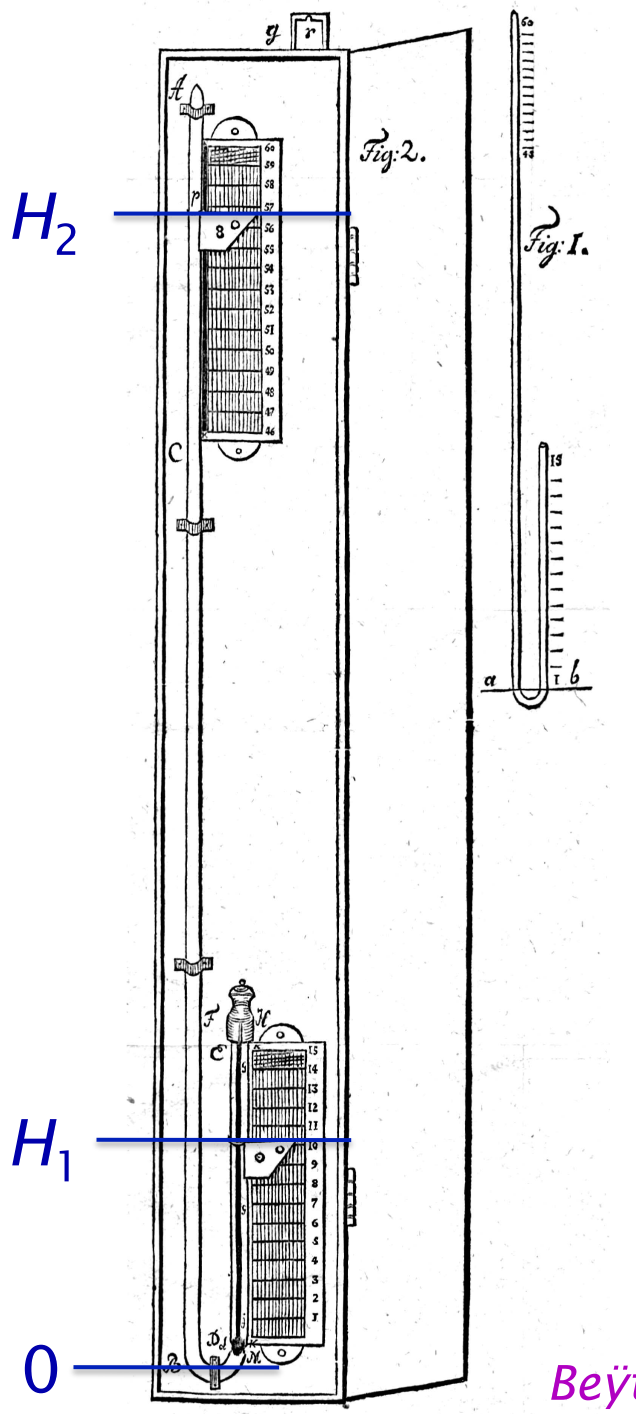
Gotha,
bey Carl Wilhelm Ettinger.
1782.

- Builds an "improved" version of Deluc barometer also makes thermometers, sells them to such luminaries as Goethe
- Publishes his meteorological observations
- As Deluc, interested in *measuring differences of elevation by means of a barometer:* he ascends the Brocken in 1780
- 1782 and 1784: Publication of his opus magnum

Beÿträge zur der Verfertigung,
der wissenschaftlichen Kenntniß,
und dem Gebrauche meteorologischer Werkzeuge
http://www.e-rara.ch/doi/10.3931/e-rara-11618

Bd. 1: Barometers and thermometers, barometric hypsometry (>330 p.)
Bd. 2: Barometric hypsometry (>350 p.)

Rosenthal's mercury barometer



Deluc : first to boil the mercury!
=> Reproducible measurements

- Transportable siphon barometer, as Deluc's
- Tube of *uniform bore* fixed on a wood plank
- Reading on 2 brass scales with movable indices

$$H = H_2 - H_1$$

- The scales: *decimal* graduation in "scruples"

1 scr = 1/16 line = 1/(12x12x16) "pied de Roi"

=>1 scr ≈ 0.141 mm

- Thermal expansion of Hg (density) and of support (linear) cannot be neglected!

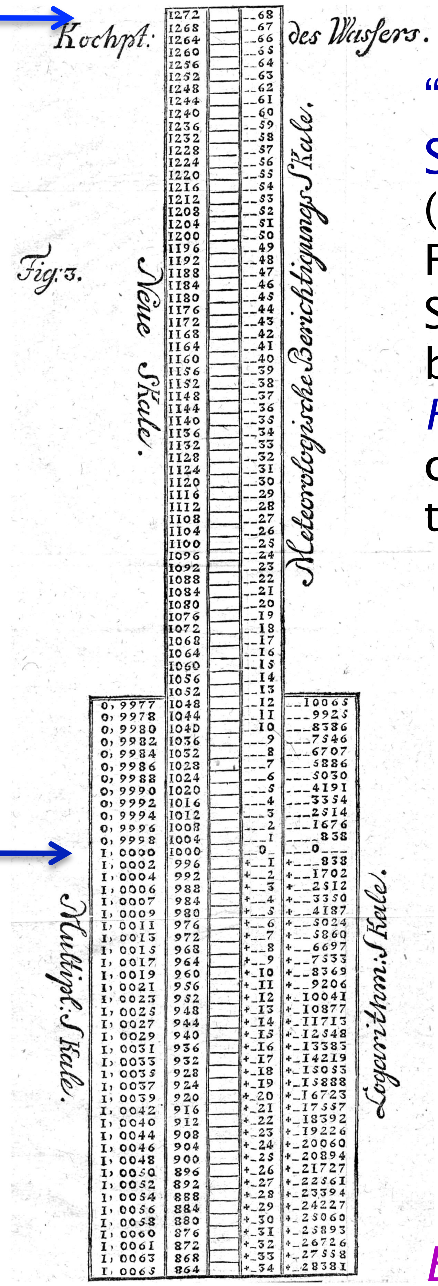
But a separate thermometer is *not* needed, this barometer displays its own temperature!

$$H_2 + H_1 \sim T$$

Beÿträge, Bd. 1, Fig. 1 & 2, S. 36

Rosenthal's mercury thermometer: the 4 scales

T_{bw} = 1272 = 100 ˚C



"Neue Skale" (new scale):
the only **temperature** scale,
from 864 (bottom, −18.6˚C) to
1272 (top, "Kochpt. des Waßers")

"Meteorologische Berichtigungs Skale"
(meteorological correction scale):
From +34 (bottom) to −68 (top)
Shows the number of scruples
by which a column of Hg of length
H_{ref} (= 5184 scr = 27'') expands or
contracts when not at the reference
temperature T_{ref} = 1000 (≈ 20.9 ˚C)

=> α_{barom} = 165.9 e−6/˚C
(true value for Hg alone 180.2)

T_{ref} = 1000

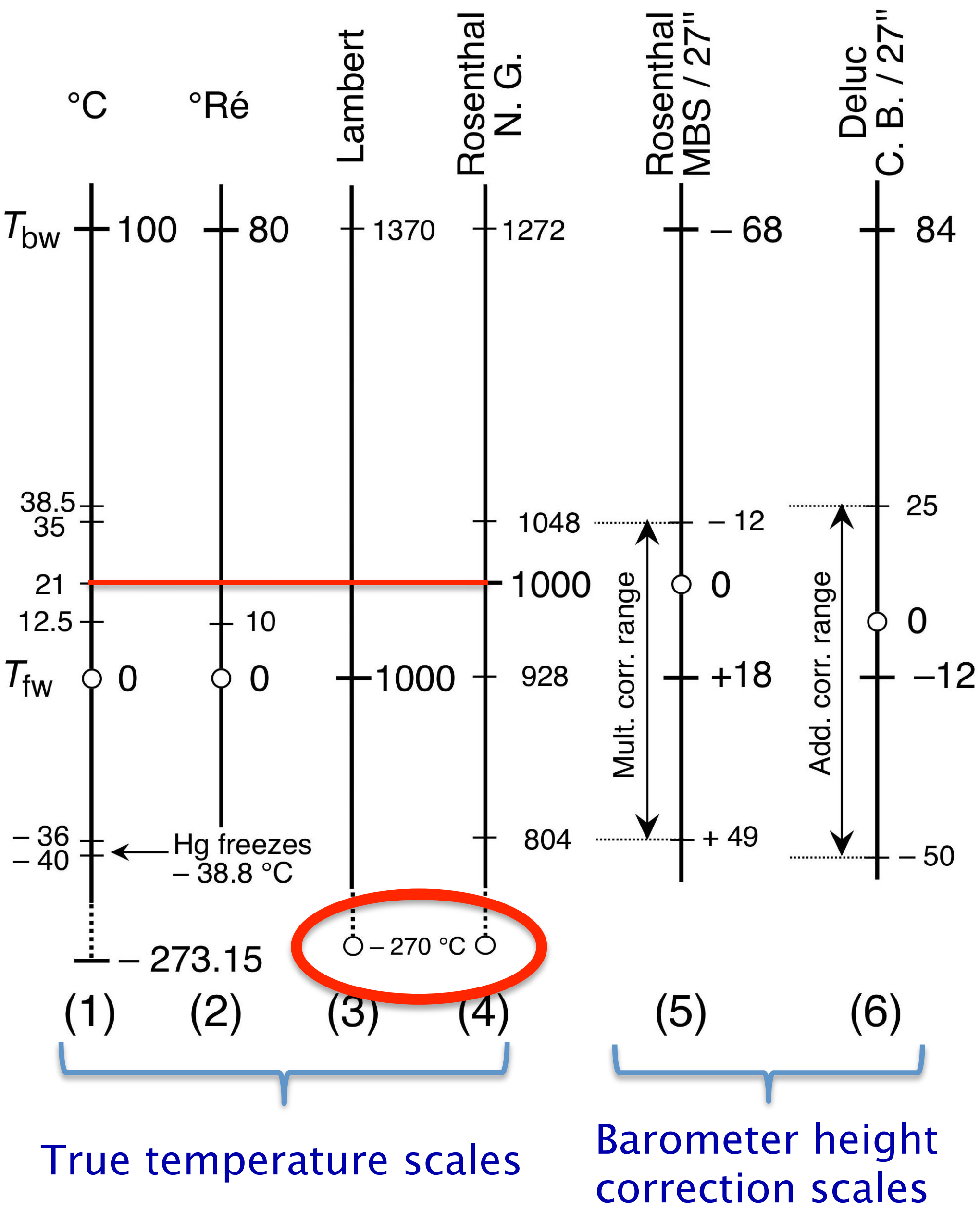
"Multipl. Skale"
(multiplication scale M):
a measurement of the thermal
expansion of Hg, used for the
reduction of H at T to H_t at T_{ref}

$H_t = H \cdot M(T)$
$M = 1$ at T_{ref}

"Logarithm. Skale":
1e7 · $\log_{10} M(T)$
Simplifies the reduction
of H to H_t
Multiplication => addition,
if Log table available

Beÿträge, Bd. 1, Fig. 3, S. 36

Comparison of a few temperature scales



1. Modern Celsius: **Two** fixed points (formerly Centigrade)

2. Réaumur: **Two** fixed points
Was in common use on the Continent

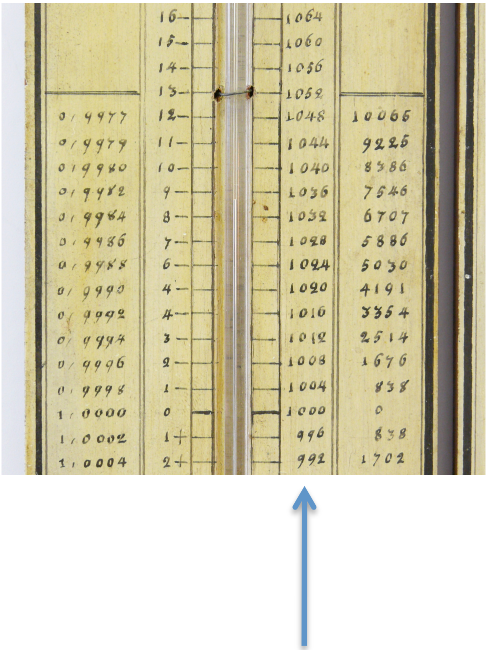
3. J. H. Lambert ("*Pyrometrie*", 1779) studies **Air Thermometers**
One fixed point (T_{fw} = 1000)
A volume of air of 1000 at $T = T_{fw}$ expands to 1370 at $T = T_{bw}$
=> T_{bw} (Lambert) = 1370

Lambert (and later Rosenthal) were convinced that *the air thermometer shows the true degree of heat*.

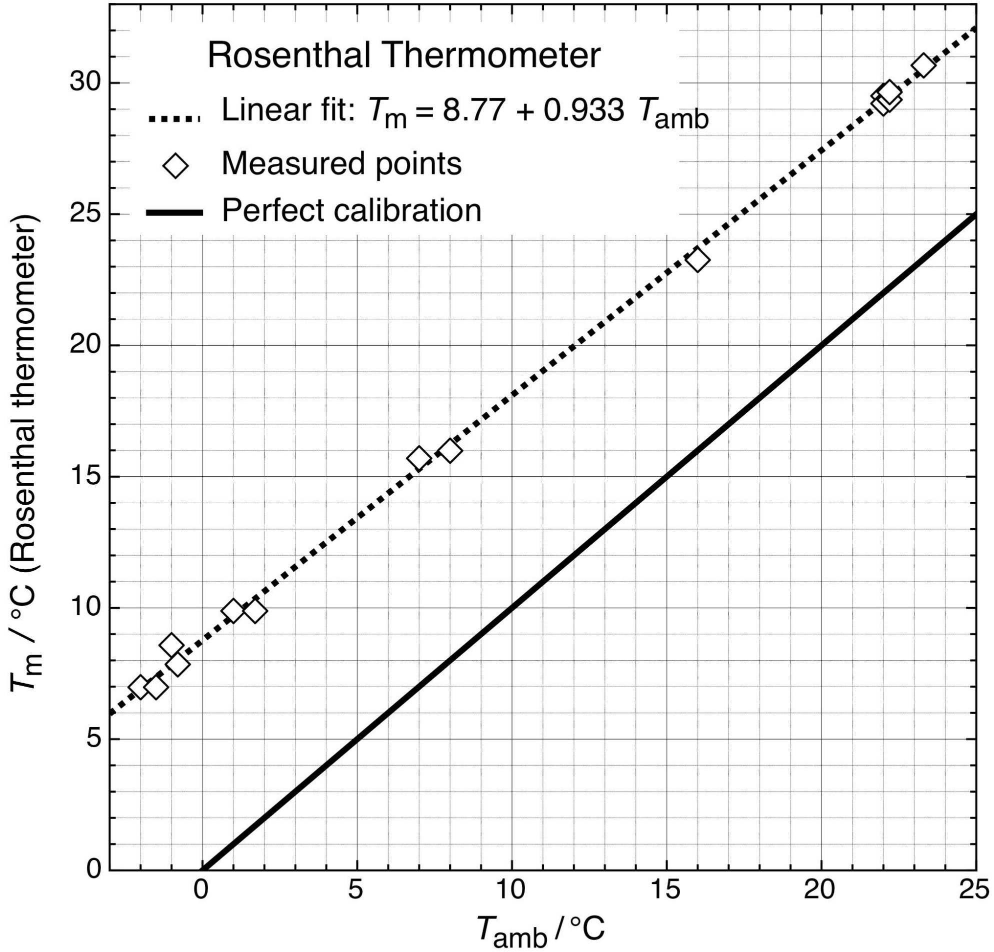
But they don't comment on the extrapolation of their scales to 0:
0 (Lambert, Rosenthal) ≈ – 270 °C !

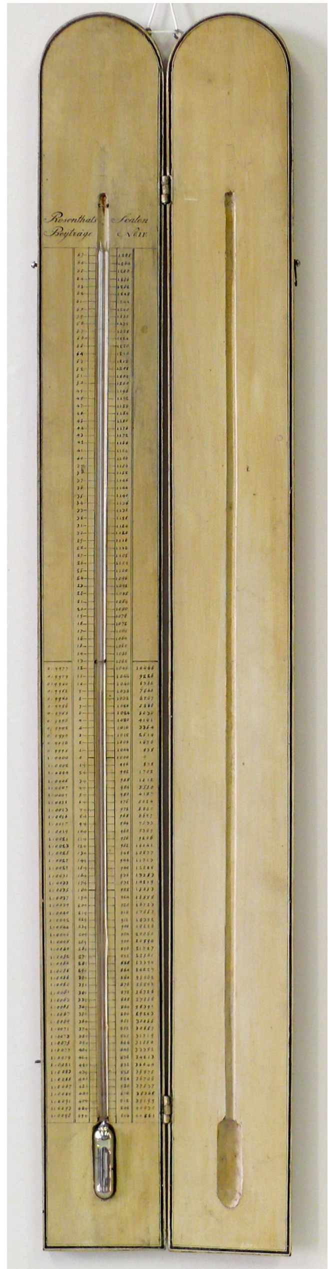
4. Rosenthal **mercury** thermometer "Neue Skale" like Lambert's, but T_{ref} = 1000 (≈ 20.9 °C) and T_{fw} = 928

Lausanne thermometer (Inv. 603.096): calibration



"Neue Skale"





The mercury tube has been replaced!

Barometric hypsometric measurements: formulas

Empirical value: $\Delta h =$ 15 to 10 m/mmHg

****

E. Halley (1686) proposed: $\Delta h = K \cdot \log (H_0 / H)$

but his formula was not accepted

J.-A. Deluc confirmed experimentally the validity of Halley's formula, ascending the mountains in the Alps around Geneva, especially the Salève, of elevation above the lake already measured geometrically.

He was the first to introduce a correction for the temperature of the column of air, by means of its mean value. He published his results in his influential treatise of 1772, 2nd edition in 1784.

****

Rosenthal, using his « absolute » air temperature scale, uses:

$$\Delta h = K \cdot [(T_0 + T)/2000] \cdot \log (H_0 / H)$$

$K \approx 10'000$ when Δh is measured in toises

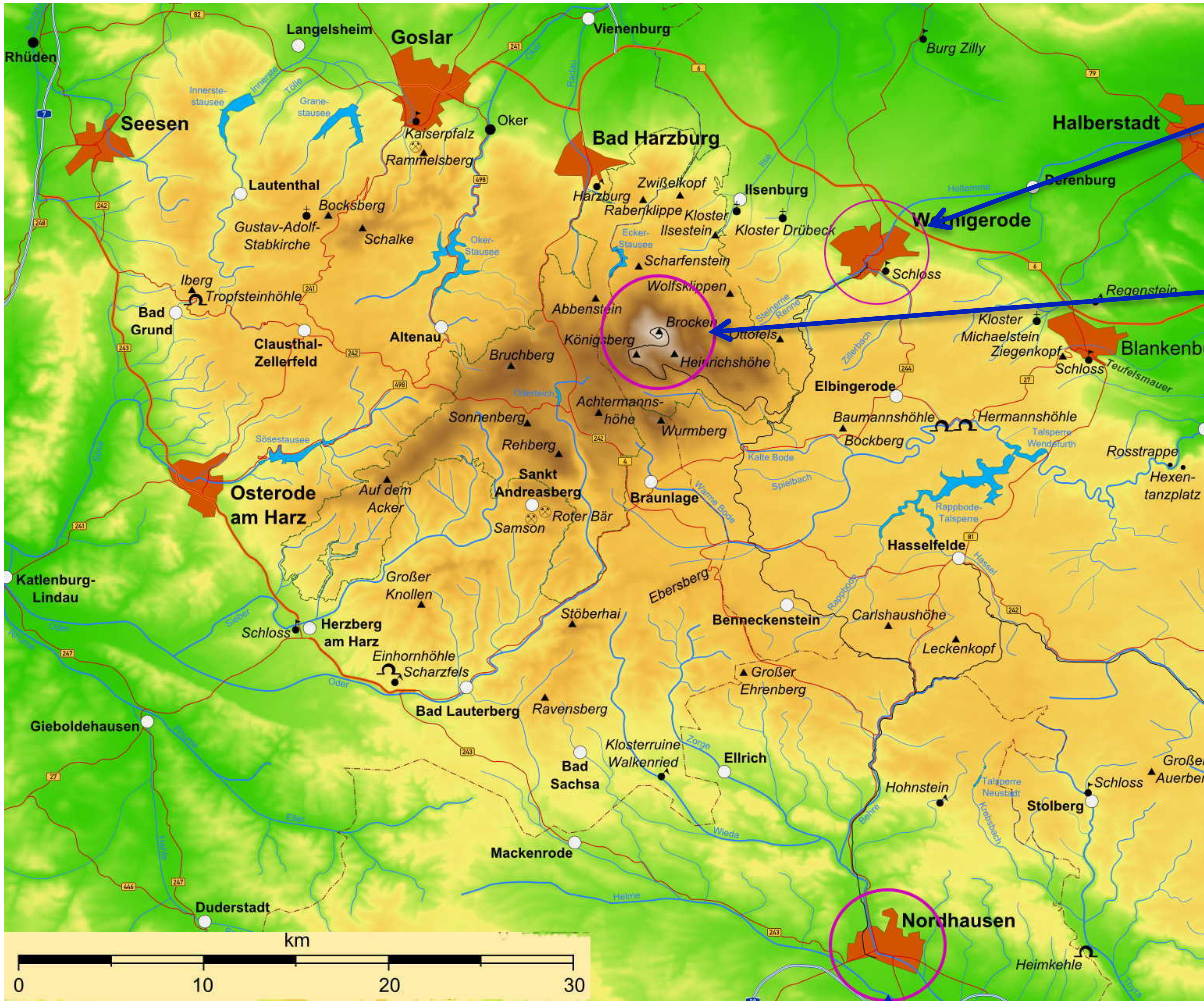
(1 toise = 6 "pieds de Roi" ≈ 1.949 m)

Barometric hypsometric measurements: procedure

Location	$h = 0$		$h = X > 0$
Measure	t, H_{10}, H_{20}, T_0		t, H_1, H_2, T
Calculate	$\alpha_0 = H_{10} - H_{20}$ $\beta_0 = H_{10} + H_{20}$	$< T > = (T_0 + T)/2$	$\alpha = H_1 - H_2$ $\beta = H_1 + H_2$
Formulas	$H_0 = L \cdot \alpha_0 / \beta_0$	$H_0 / H = (\alpha_0 \cdot \beta) / (\beta_0 \cdot \alpha)$	$H = L \cdot \alpha / \beta$
Use logs table		$+ \log \alpha_0$ $- \log \beta_0$ $+ \log \beta$ $- \log \alpha$	
Sum		X_{raw} / 10’000	
Elevation in toises		$X = 10 \cdot < T > \cdot X_{raw}$	

t : time, the same for the 2 locations
H : barometric readings (arbitrary units)
T : air temperature (Rosenthal’s “Neue Skale”)
(L : total (constant) length of the mercury column at $T = T_{ref}$)

Rosenthal's barometric hypsometric measurements



Title page view

The Brocken

Rosenthal ascends the Brocken in July 1780, takes many measurements, one observer remaining at Nordhausen.

Itinerary, stations not precisely known.

Δh (Nordhausen–Brocken) = 488 toises = 951.2 m

$180 \text{ m} < h_{\text{Nordhausen}} < 220 \text{ m}$

$\Rightarrow h_{\text{Brocken}} \approx 1151 \text{ m}$

(actually 1141 m)

In and around Nordhausen

Conclusions

- Best hypsometric accuracy obtained by triangulation, either terrestrial (theodolite) or celestial (satellites such as GPS).

- Barometric elevation measurements remain of limited precision, but are nowadays done quickly with simple instruments (no more mercury!): thus still used for navigation above earth (gliders, ballooning, …) or where GPS does not reach: in deep canyons, inside buildings, under earth, …

- G. E. Rosenthal was not a genius, but a rather eccentric character who brought an original contribution to meteorology, far from important scientific centers:

— decimal barometric scale,
— self-correcting barometer (Hg temperature),
— “absolute” air temperature scale,
— elevation calculations simplified by using logarithms.

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App. 1: Conversion of temperature scales: exact formulas

	Scale s	Temperature t / °C	T_{fw} / °C	T_{bw} / °C	$s = 0$ [°C]
1	Lambert (air)	$(s - 1000) \cdot 10/37$	1000	1370	≈ – 270
2	Rosenthal NS	$(s - 928) \cdot 25/86$	928	1272	≈ – 270
3	Réaumur	$s \cdot 5/4$	0	80	0
4	Fahrenheit	$(s - 32) \cdot 5/9$	32	212	≈ – 17.8
5	Celsius (original)	$100 - s$	100	0	100
6	Christin or "de Lyon"	s	0	100	0
7	Delisle (or de Lisle)	$100 - (2\, s / 3)$	150	0	100
8	Deluc (or De Luc) – 186 div.	$(s + 39) \cdot 50/93$	– 39	147	≈ 21
9	Deluc – 96 div.	$(s + 12) \cdot 25/24$	– 12	84	12.5
10	Rosenthal MBS	$(18 - s) \cdot 50/43$	+ 18	– 68	≈ 20.9

1 to 8: True temperature scales

The Fahrenheit scale was and still is in common use
The Delisle scale was also fairly common, besides many other scales
The original centesimal Celsius scale (100 to 0) was reversed by Christin (from Lyon) to become the ancestor of the modern Centigrade, now Celsius scale

9 and 10: Barometer height correction scales,

based on the thermal expansion of mercury, as proposed by Deluc and Rosenthal

App. 2: Mercury Barometer: temperature correction

Barometer readout $H = H_2 - H_1$ depends on
- the mercury density (or the thermal expansion per unit of volume),
- the linear expansion of the scale (wood, later brass, …),

both functions of temperature.

Last quarter of the XVIIIth c.:
Rough measurements of the expansion of a Hg column of length H_{ref} at T_{ref} in situ in the barometer, in a very limited range of temperatures

Deluc:
ΔH = 96/16 line on H_0 = 27'' (extrapolated 0˚C to 100˚C) => α_{barom} = 182.5 e-6/˚C
Interval 0˚C to 100˚C divided in 96 parts (1/16 line), centered on T_{ref} = 12.5˚C
Scale directly used for the correction (graphical method)

Rosenthal:
ΔH = 86/16 line (27'', 0˚C to 100˚C) => α_{barom} = 165.9 e-6/˚C
Interval 0˚C to 100˚C divided in 86 parts ("scruples"), centered on T_{ref} = 20.9˚C
Scale not used for actual correction during his trips with his siphon barometer!
For barometers with two tubes of different diameters, or for cistern barometers, Rosenthal prefers the arithmetic calculation based on M and log M

First barometer with a complete movable brass scale: A. Pictet, Geneva 1803

The cathetometer invented by Dulong and Petit in the early XIXth c., allows precise laboratory measurements of thermal expansion in a wide range of temperatures:
1817: α_{Hg} = 180.18 e-6/˚C Brass: 18.4 e-6 Wood ≈ 5.5 e-6 (pine)

App. 3: Rosenthal's siphon barometer: it can be used as a thermometer!

$H_2 + H_1 = L\ (1 + \alpha \cdot \Delta T)$

H_2 and H_1 are the long arm and the short arm barometer readings

L is the total length of the mercury column, at $T = T_{ref}$;

it's a constant for a given barometer

α : thermal expansion coefficient of mercury (per unit of volume)

$\Delta T = T - T_{ref}$, where T_{ref} is some fixed reference temperature

H is the true barometer height, reduced at $T = T_{ref}$:

$H_2 - H_1 = H\ (1 + \alpha \cdot \Delta T)$

$(H_2 - H_1) / H = (H_2 + H_1) / L$

$H = L \cdot (H_2 - H_1) / (H_2 + H_1)$

Halley and De Luc: calculate the ratio H_0 (at $h = 0$) over H (at $h = X$):

L and α disappear!

c.q.f.d.