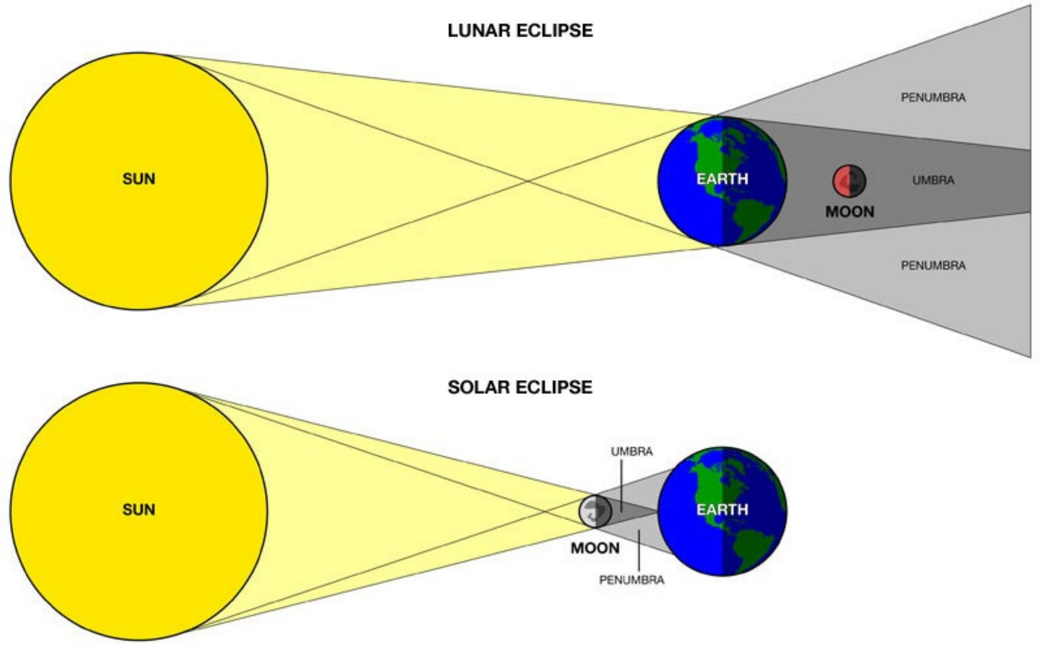
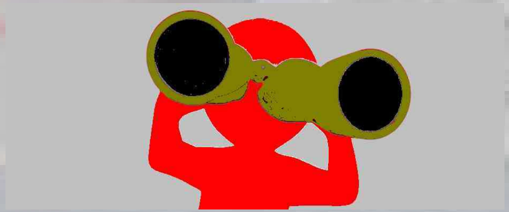
Solar Ecclipse 25 Oct 2022



Basic parameter – Which are they ?

Parameters that are used to describe ‘Weather‘ using the methods of Numerical Weather Prediction and Visibility



Air pressure

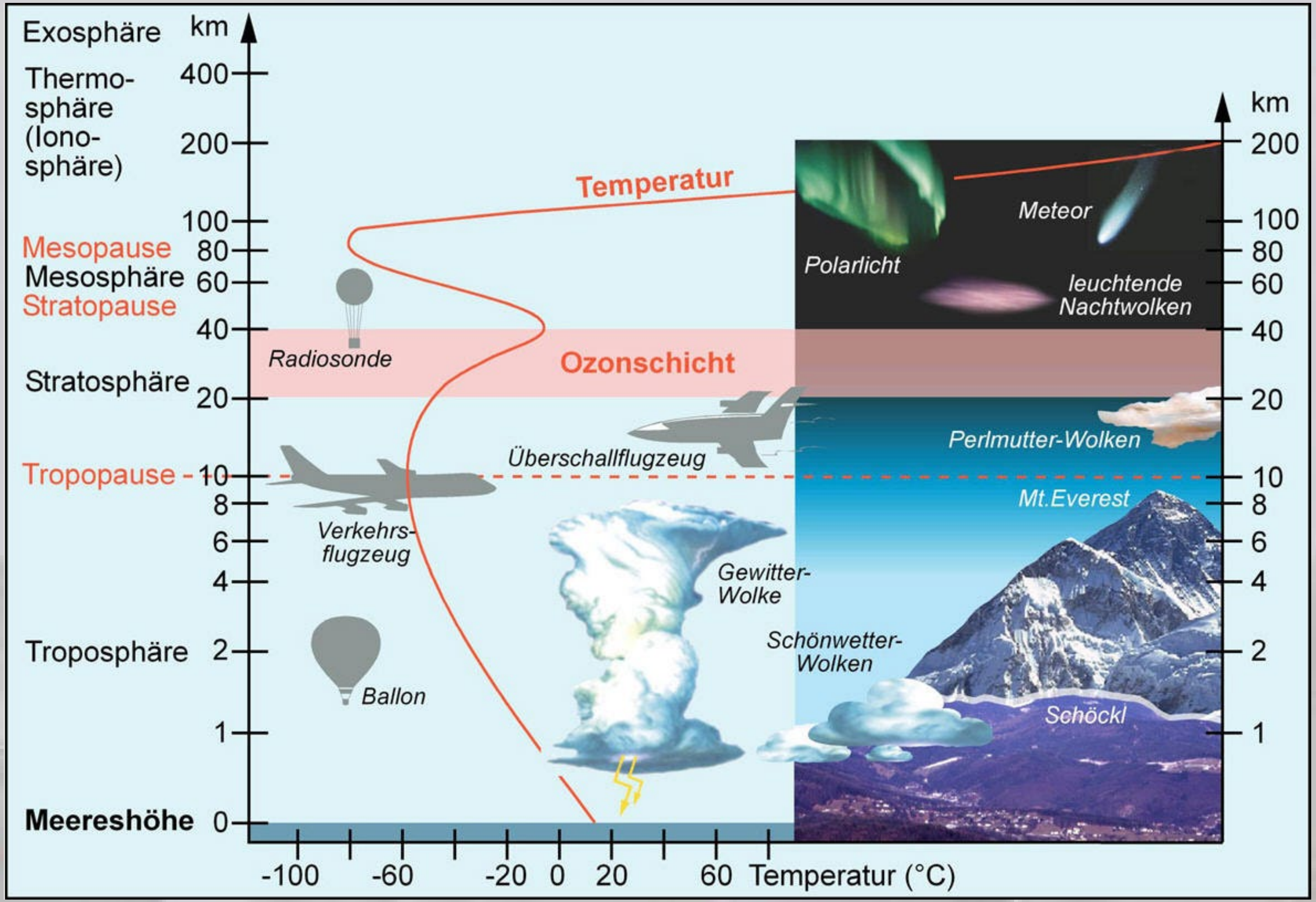
Temperature and Radiation

Air humidity

Wind direction / speed

Visibility

AIR PRESSURE: VERTICAL STRUCTURE OF THE ATMOSPHERE

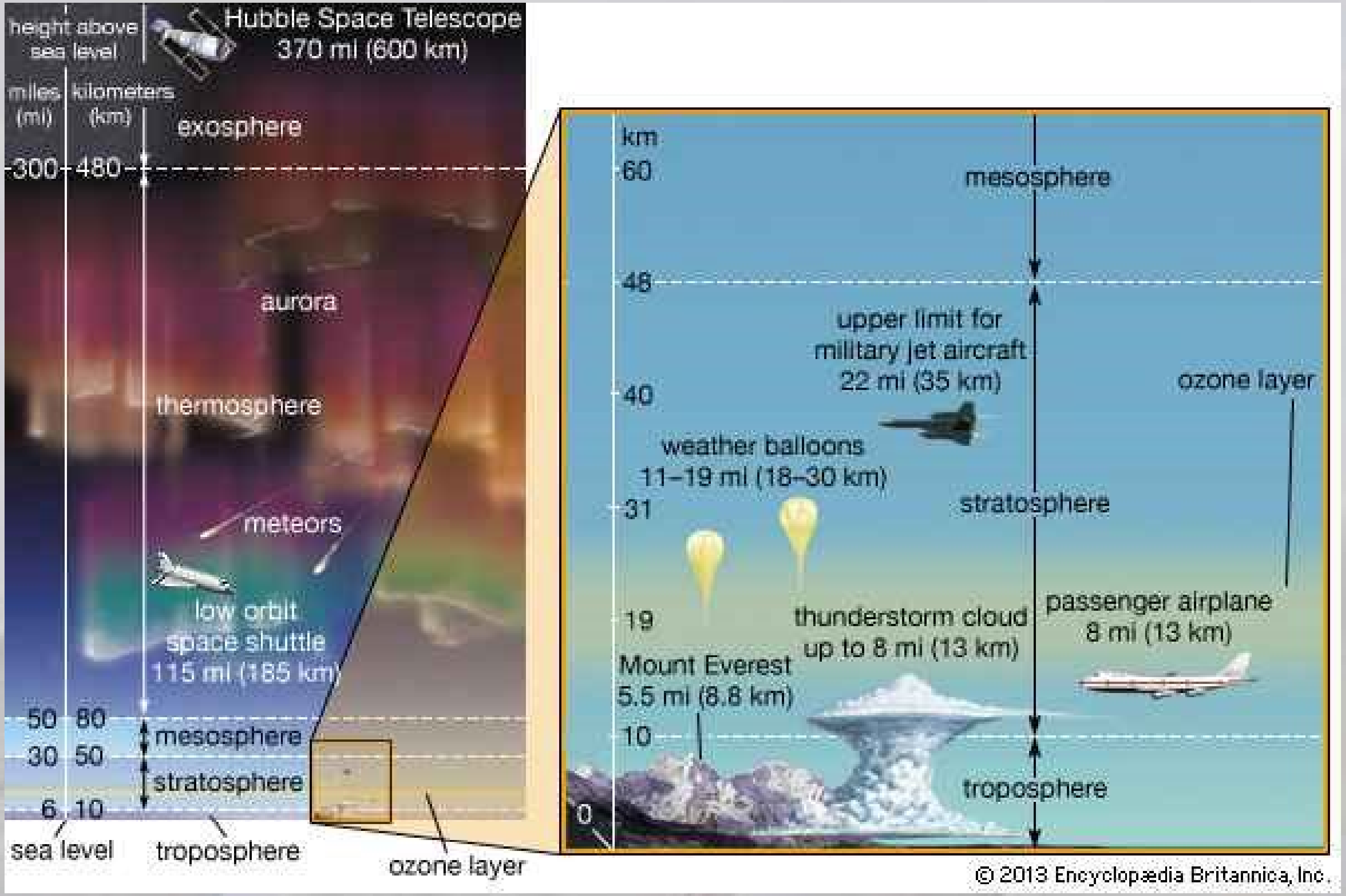


Composition of the atmosphere

Nitrogen 78 % <noble gases < 1 % (CO_2, O_3, Ar, He, H, X, Rn)

Oxygen 21 % water vapour variable between 0 % and 4 %

Air Pressure: Vertical structure of the atmosphere

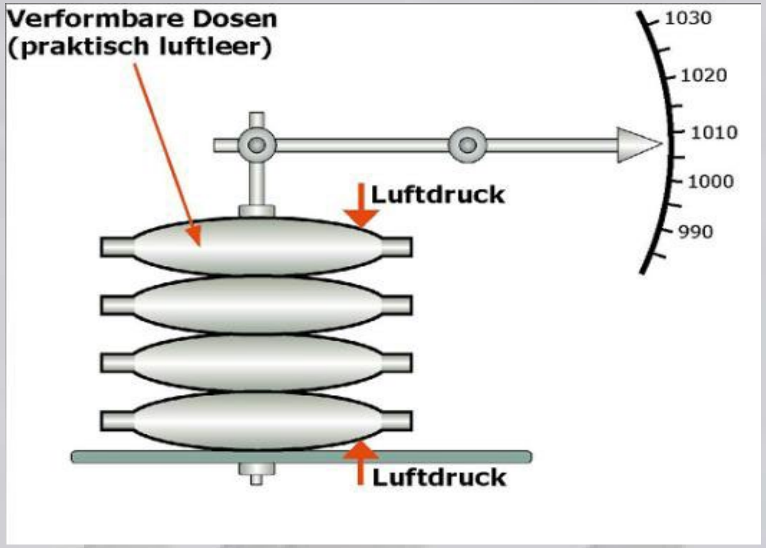


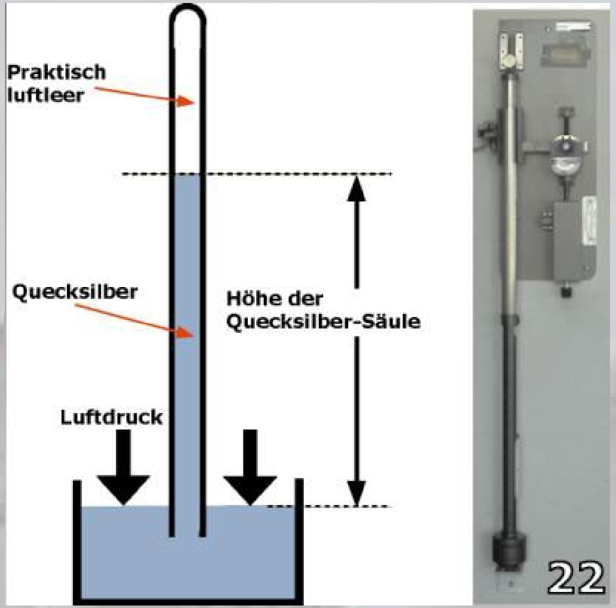
Temperature lapses with height up to Tropopause (isothermal above)

Dry-adiabatic lapse rate (no external heat) 1 °C / 100m

Moist-adiabatic lapse rate (no ext. heat, condensation) 0.6 °C / 100m

Air pressure: Measurement





Android* barometer

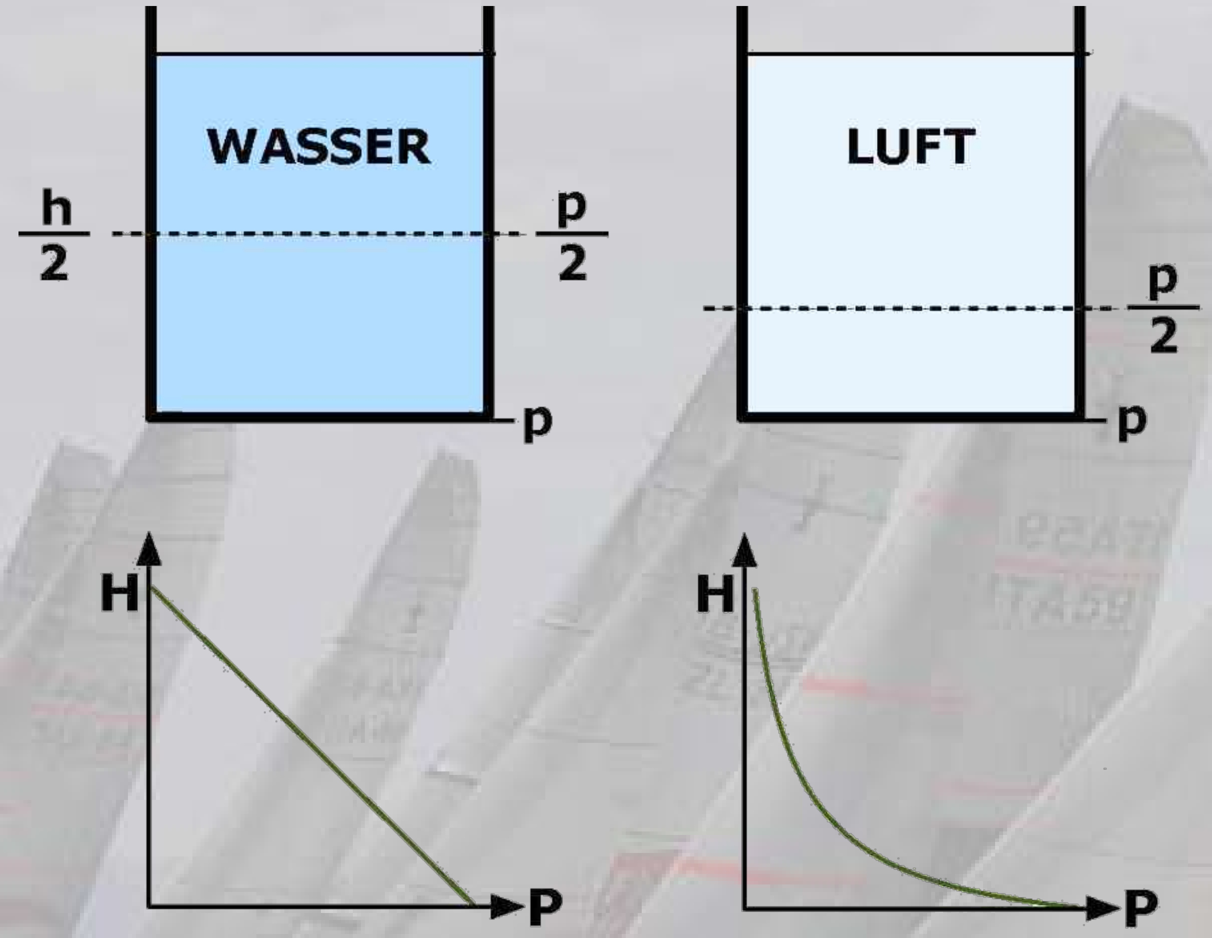
The atmosphere exerts pressure on one or more aneroid capsules. The resulting extent is transferred via a lever to a scale.

Mercury barometer

The atmosphere exerts pressure on the surface of mercury with an inverted vacuum tube which directly indicates the air pressure

* kidding

AIR PRESSURE: VERTICAL STRUCTURE OF THE ATMOSPHERE

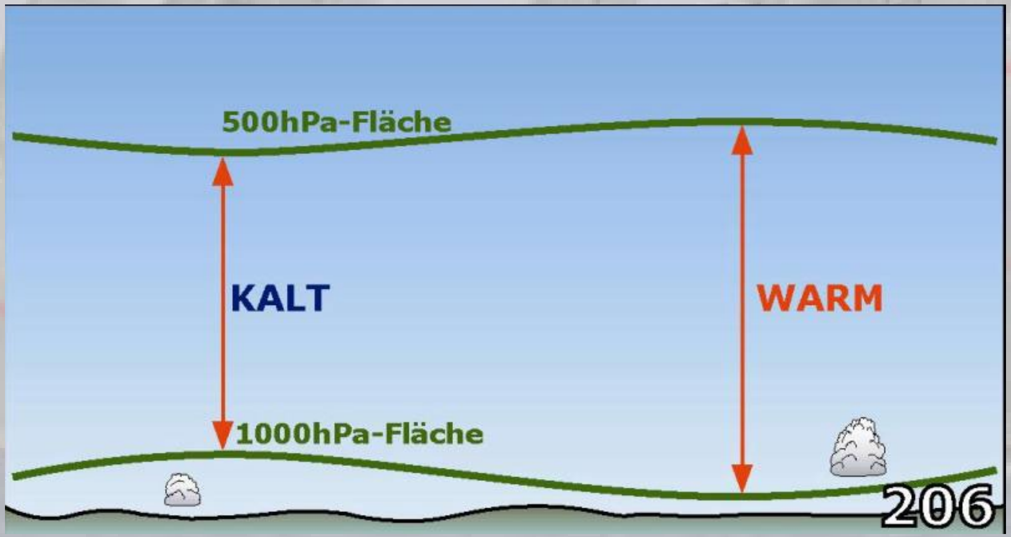


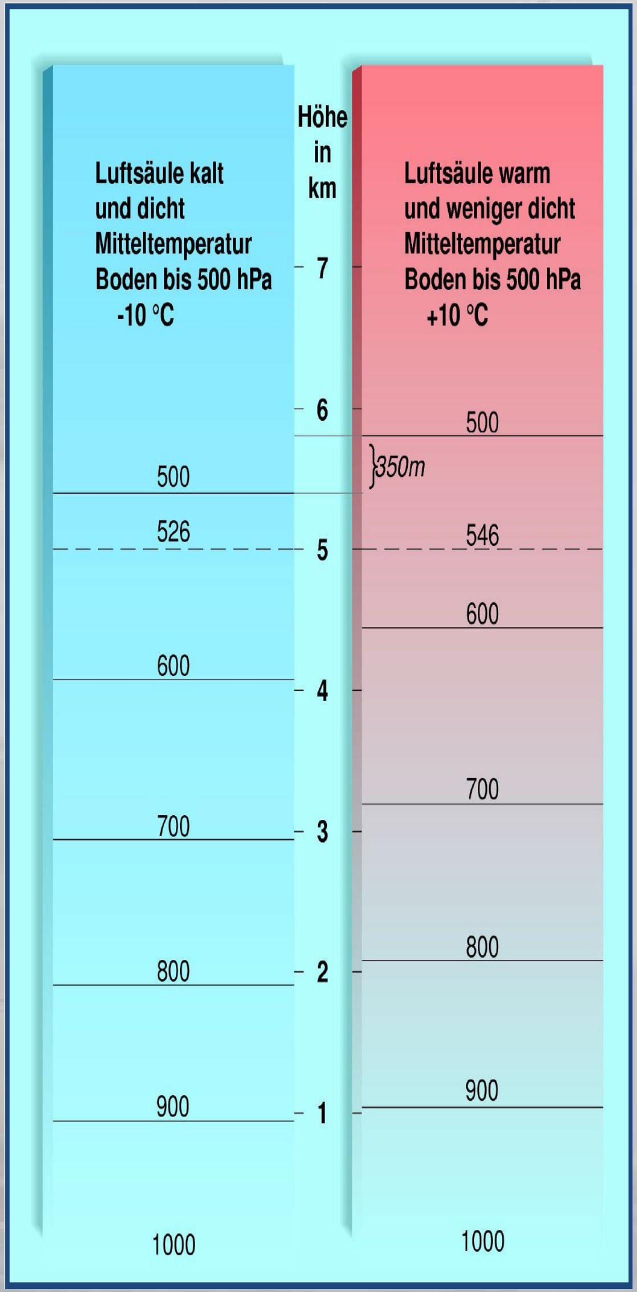
Air Pressure: Vertical structure of the atmosphere

- Given equal surface pressure, the height of a layer of constant pressure is a function of the temperature of the air below and only of this temperature

- The vertical distance between two pressure layers (e.g. 500/1000 hPa) is a function of temperature only

- The higher the temperature of the air column, the greater the height of the pressure layer

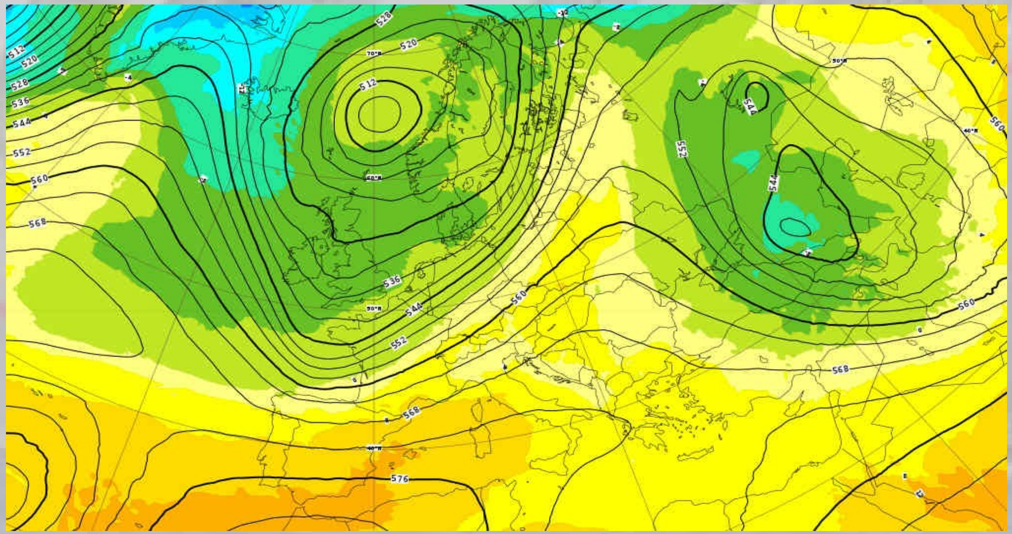


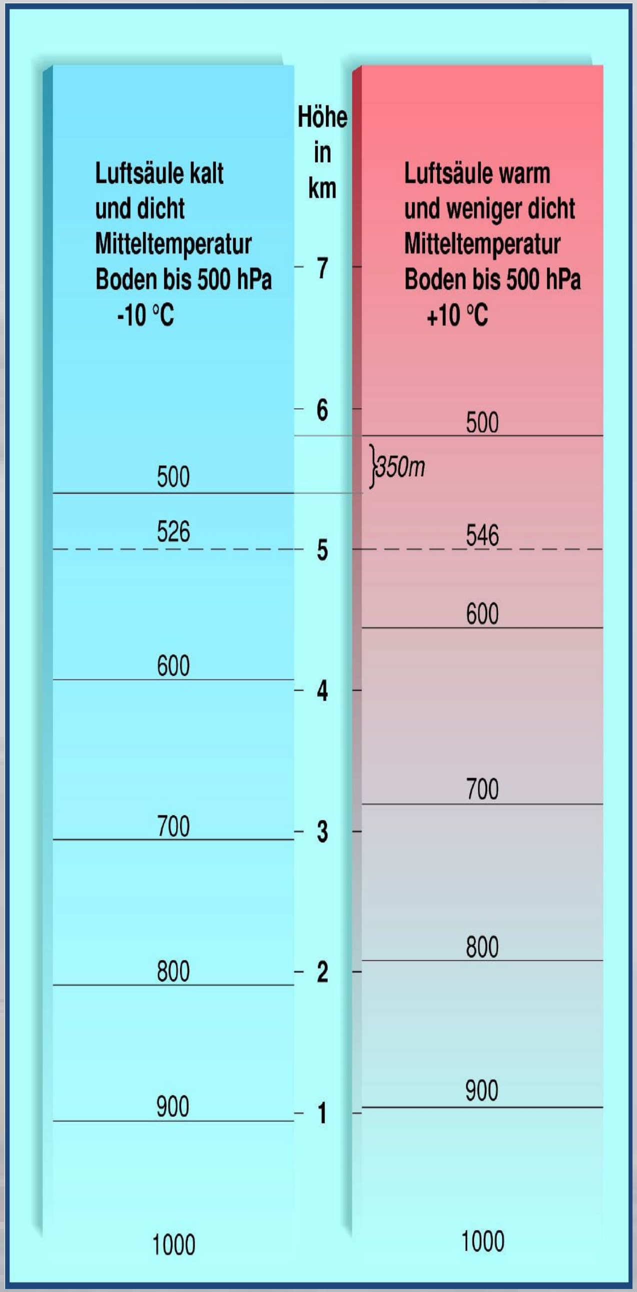


AIR PRESSURE: VERTICAL STRUCTURE OF THE ATMOSPHERE

For uper air flow (z.B. 500 hPa) holds:

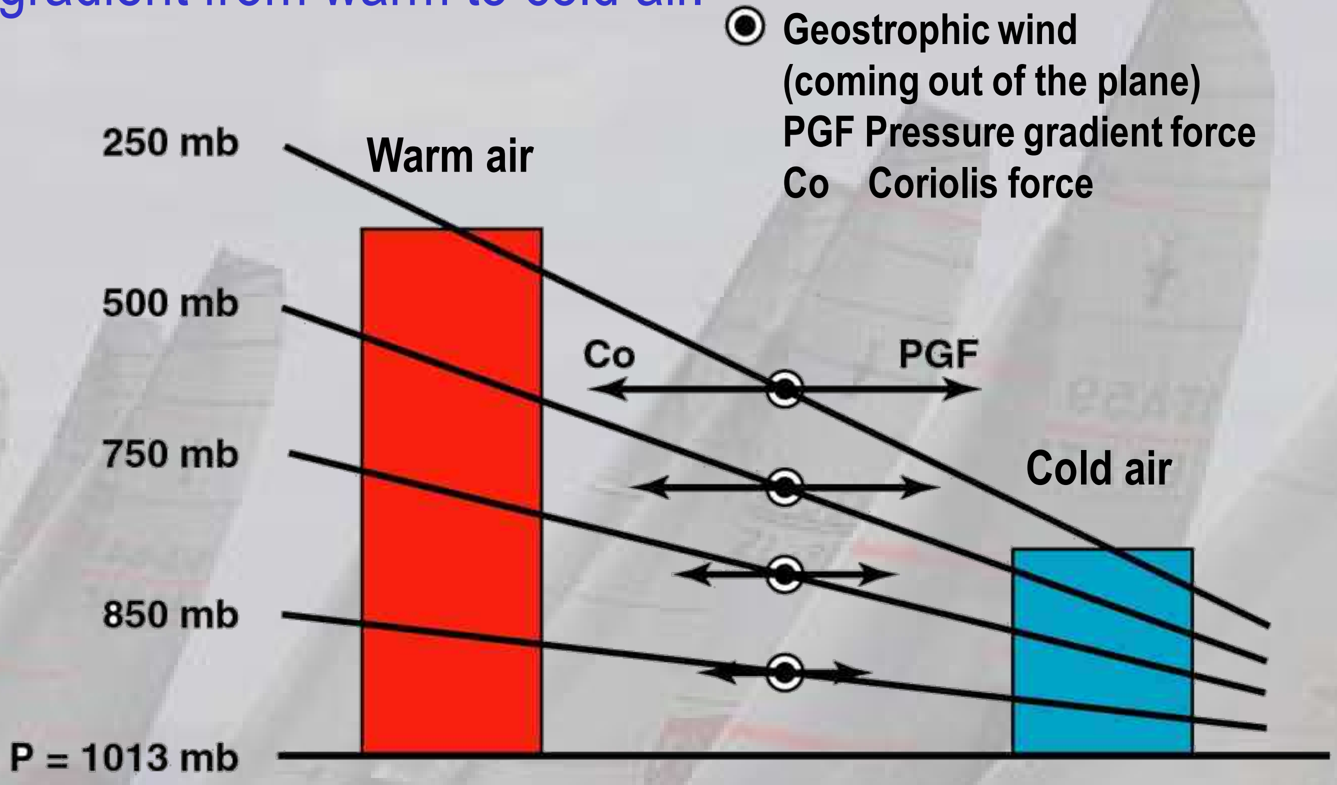
- **Cold air advection** lowers the 500 hPa layer (decrease of geopotential, trough intensification)
- **Warm air advection** lifts the 500 hPa layer (increase of geopotential, intensification of a High)
- The vertical pressure gradient is smaller in warm air than in cold air



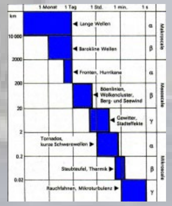


Air Pressure: Vertical structure of the atmosphere

The height of a pressure layer is a function of the mean temperature of the air column below. A horizontal temperature gradient thus results in a horizontal pressure gradient from warm to cold air.

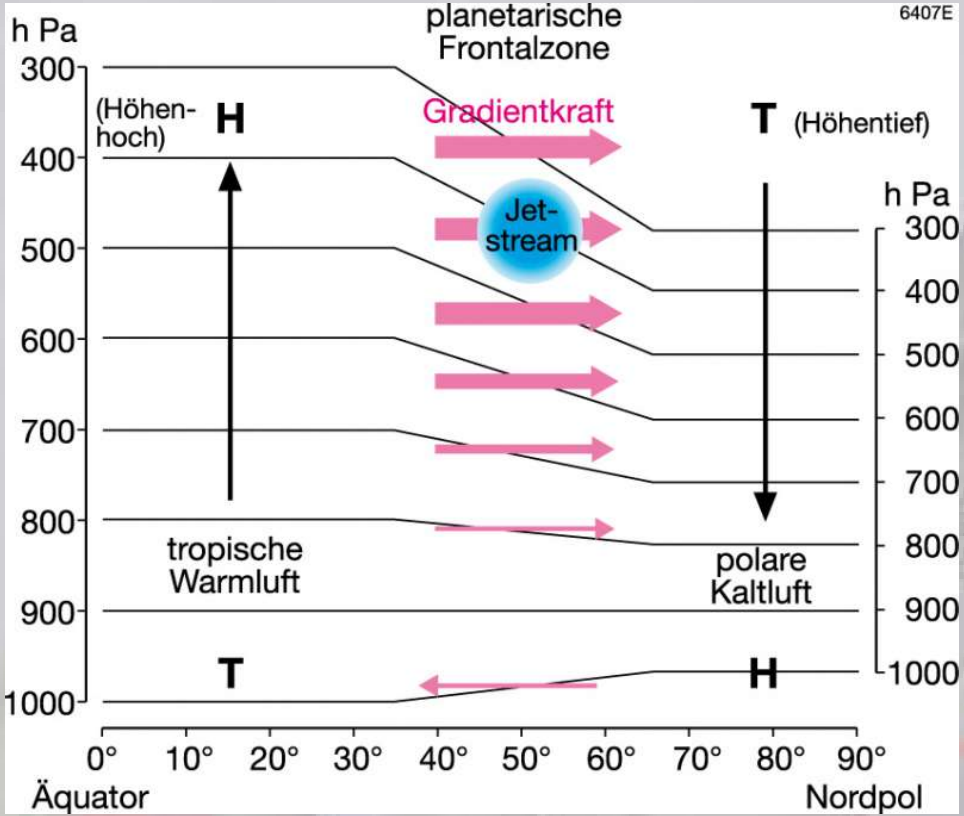


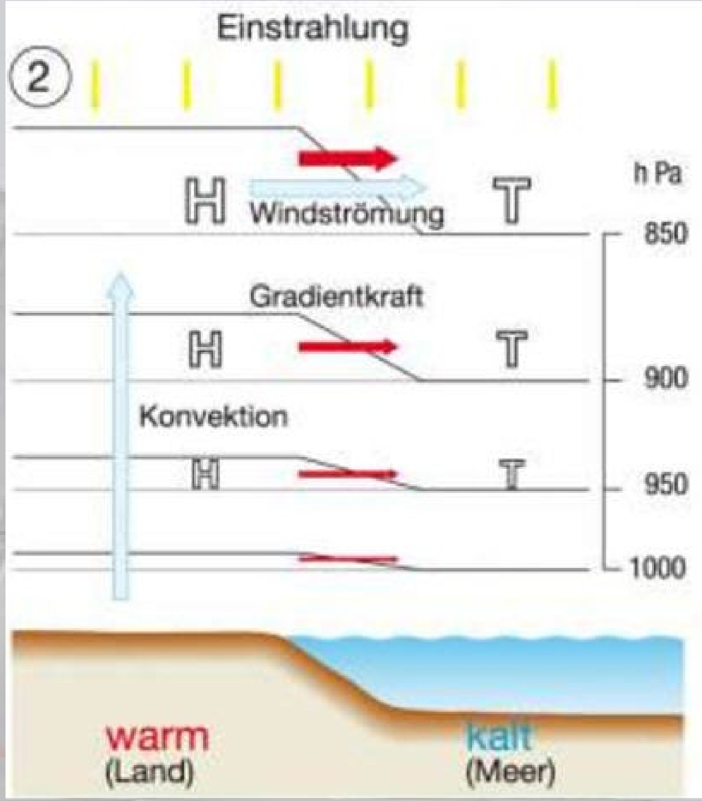
	Global circulation	Sea-breeze circulation
Horizontal scale	10000 km	10 km
Vertical scale	10 km	2 km
Time scale	months	one day



Air Pressure: Vertical structure of the atmosphere

The height of a pressure layer is a function of the mean temperature of the air column. The resulting dynamics on different space-time-scales are shown below.

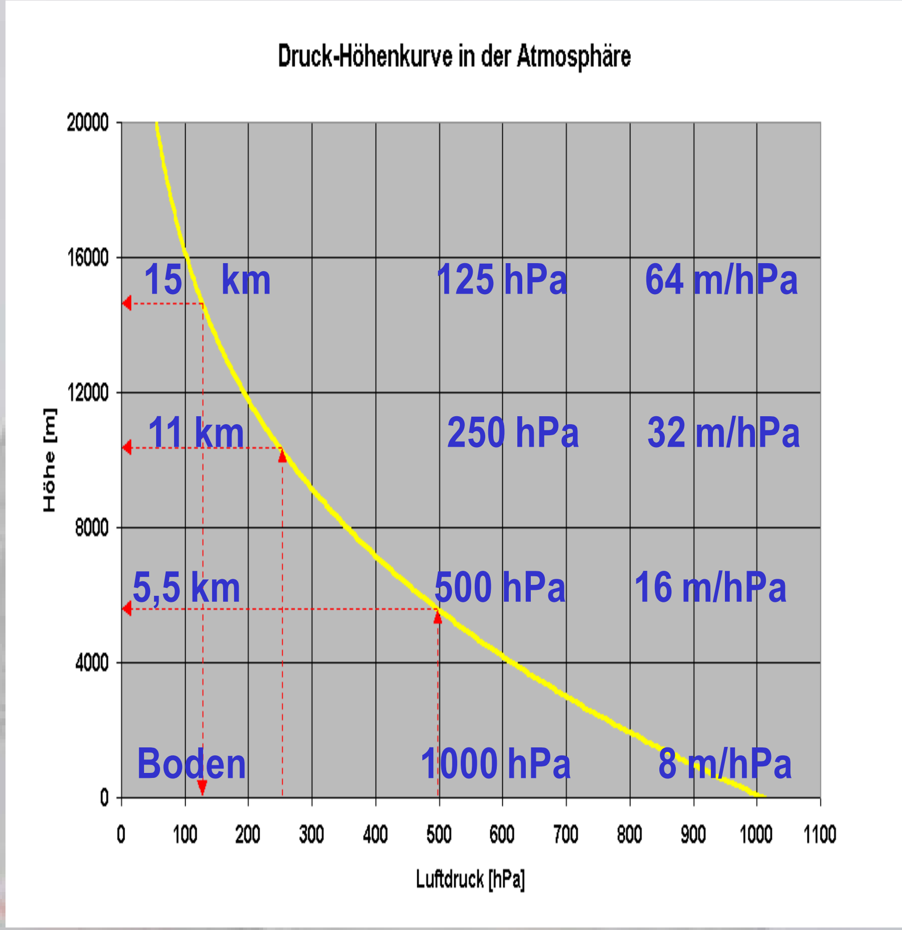




	Global circulation	Sea-breeze circulation
Horizontal scale	10000 km	10 km
Vertical scale	10 km	2 km
Time scale	months	one day

AIR PRESSURE: ICAO STANDARD ATMOSPHERE

- **Pressure lapse rate**
  - Pressure halves each 5.5 km
- **Height of unit decrease of pressure**
  - at surface 8 m / hPa
  - doubling each 5.5 km
  - a function of temperature



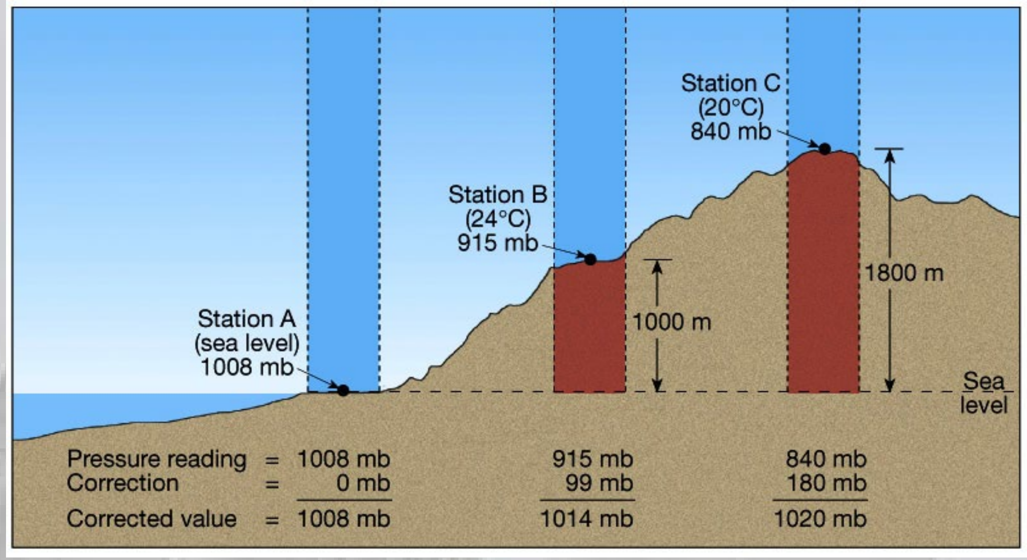
Standard Atmosphere Pressure-height-graph

AIR PRESSURE: ICAO STANDARD ATMOSPHERE

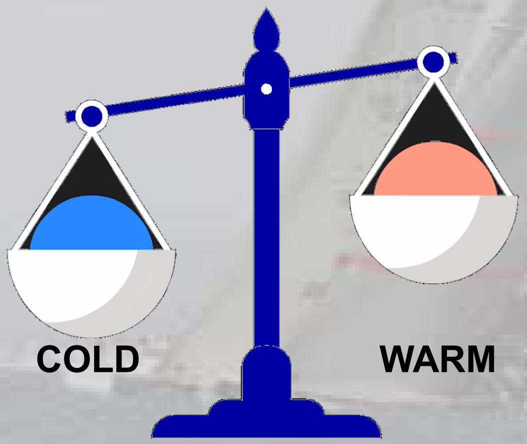
Air pressure p : Hydrostatic pressure of the air column above
The weight of the air column is determined by air density and temperature.

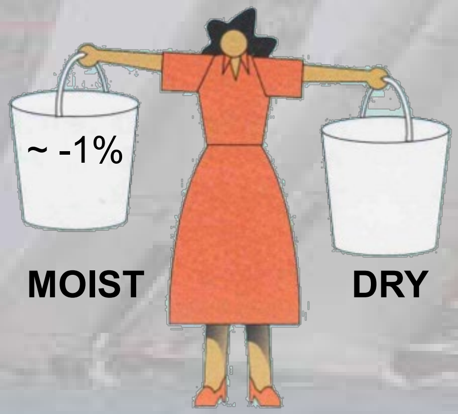
ICAO Standard Atmosphere
is dry (no moisture considered)
MSL Mean sea level values

- **Air pressure = 1013,25 hPa**
- **Air density**
  - -25°C 1,4224 kg/m^3
  - **0°C 1,3 kg/m^3**
  - 35°C 1,1455 kg/m^3



Surface pressure as a function of elevation MSL





Air density is a function of temperature and moisture

Overall mass of the atmosphere	5 * 10^{18}	kg
Overall mass of the Earth	6 * 10^{24}	kg
Mass of the air column per m^2	10 000	kg **10 t**
Earth radius (mean value)	6 371	km
Earth surface	~ 500 000 000	km^2
World population	~ 8 000 000 000	man

BASIC PARAMETERS: TEMPERATURE

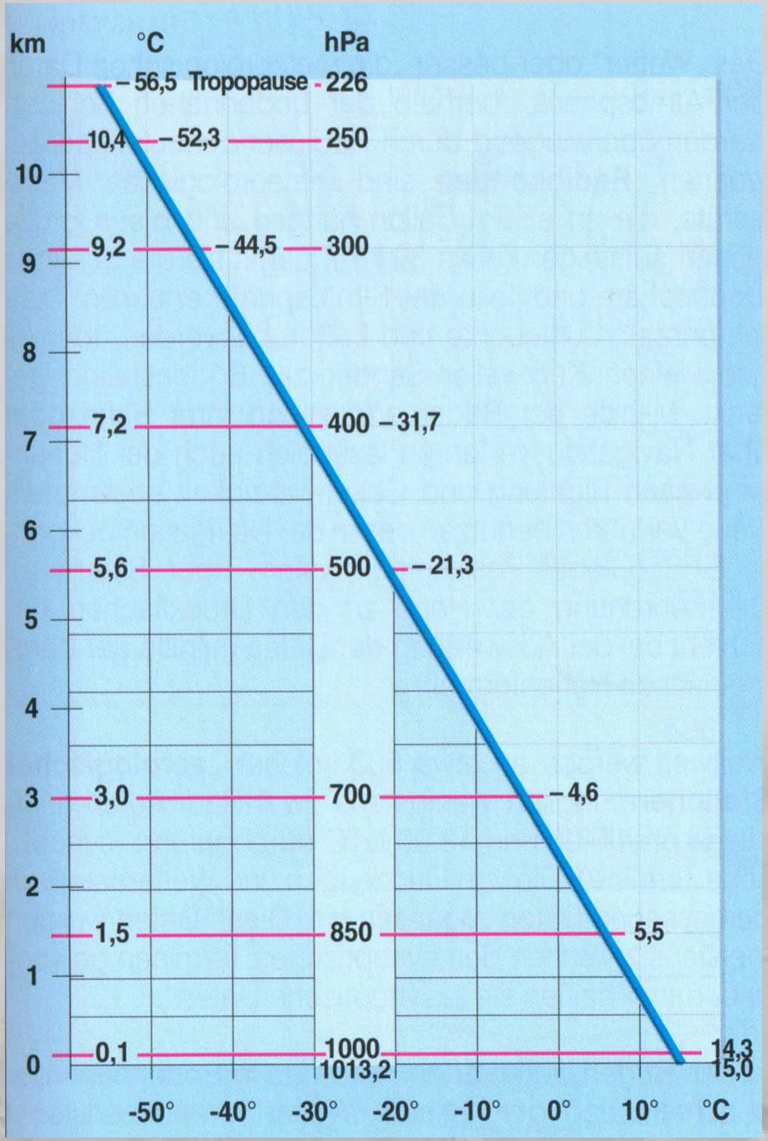
- The temperature of a gas is a function of the mean velocity of its molecules, thus describing its internal energy

- The temperature is measured either by
  - direct using a thermometer or
  - remote detecting IR radiation with a sensor

- **Temperature scales**
  - most common, also SI-unit: Celsius (°C).
  - used in the USA: Fahrenheit (°F).
  - SI-unit, used in physics and technology: Kelvin (K)

very cold winter in the Netherlands:	-17.8 °C = 0 F
freezing point of water:	0 °C = 32 F = 273.15 K
body temperature of man:	37.8 °C = 100 F
boiling point of water:	100 °C = 212 F

TEMPERATURE: ICAO STANDARD ATMOSPHERE



ICAO Standard Atmosphere

Temperature at MSL: 15 °C

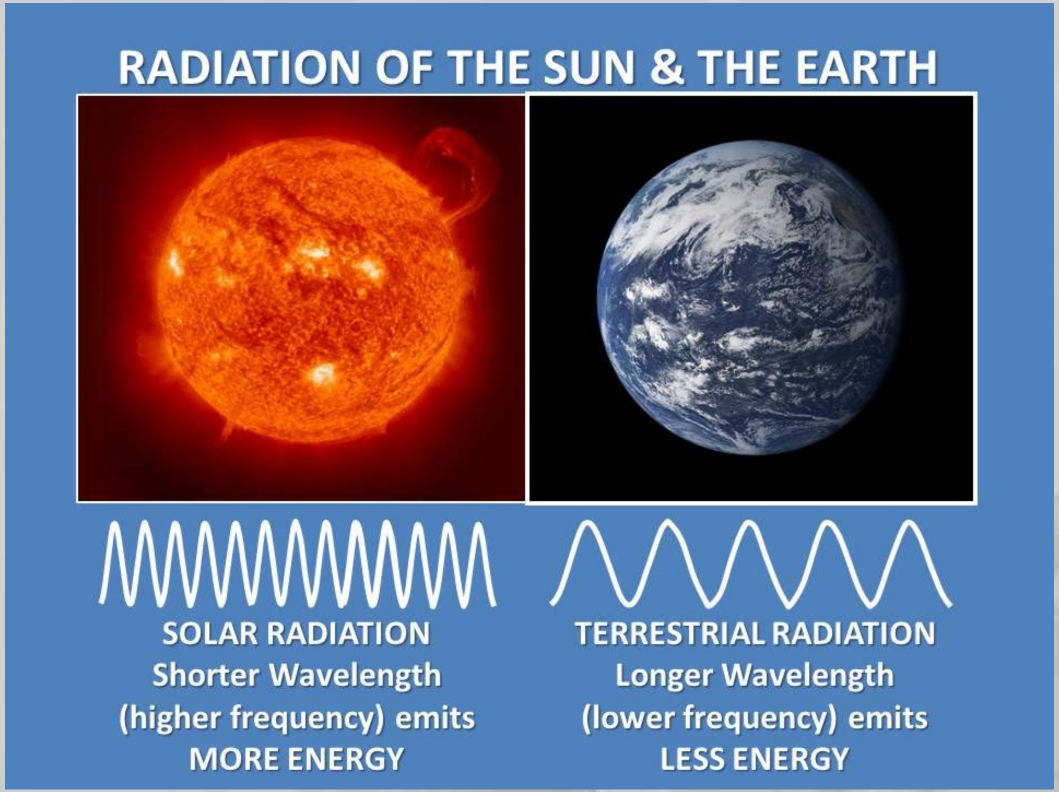
Temperature	**Lapse rate :**	**0.65 °C / 100m**
Dry-adiabatic	Lapse rate:	1.00 °C / 100m
Moist-adiabatic	Lapse-rate	0.65 °C / 100m

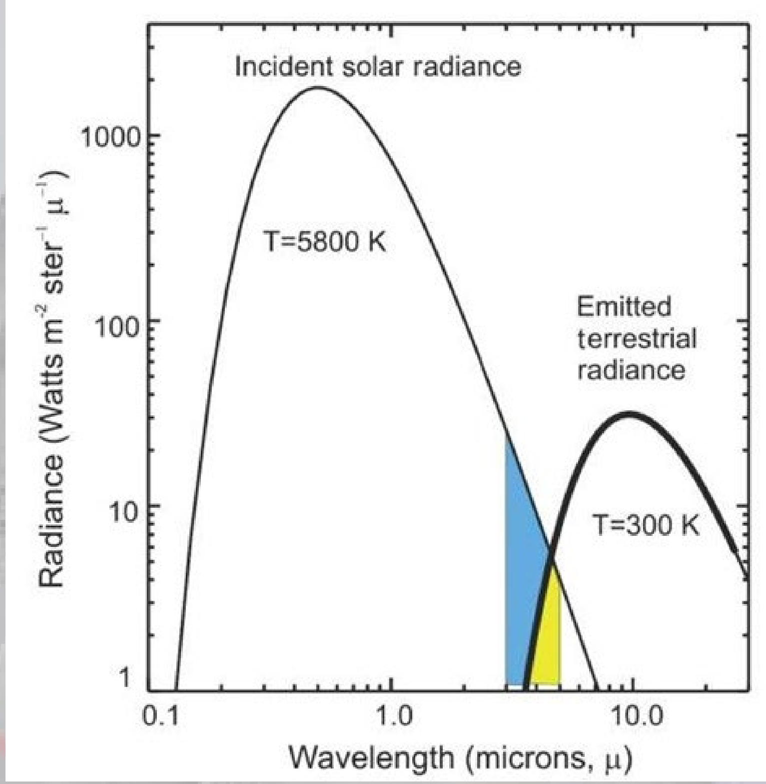
Tropopause	**Height:**	**11 km**
Tropopause	**Temperature:**	**-56 °C**

The ICAO Standard Atmosphere is dry, no Moisture is considered

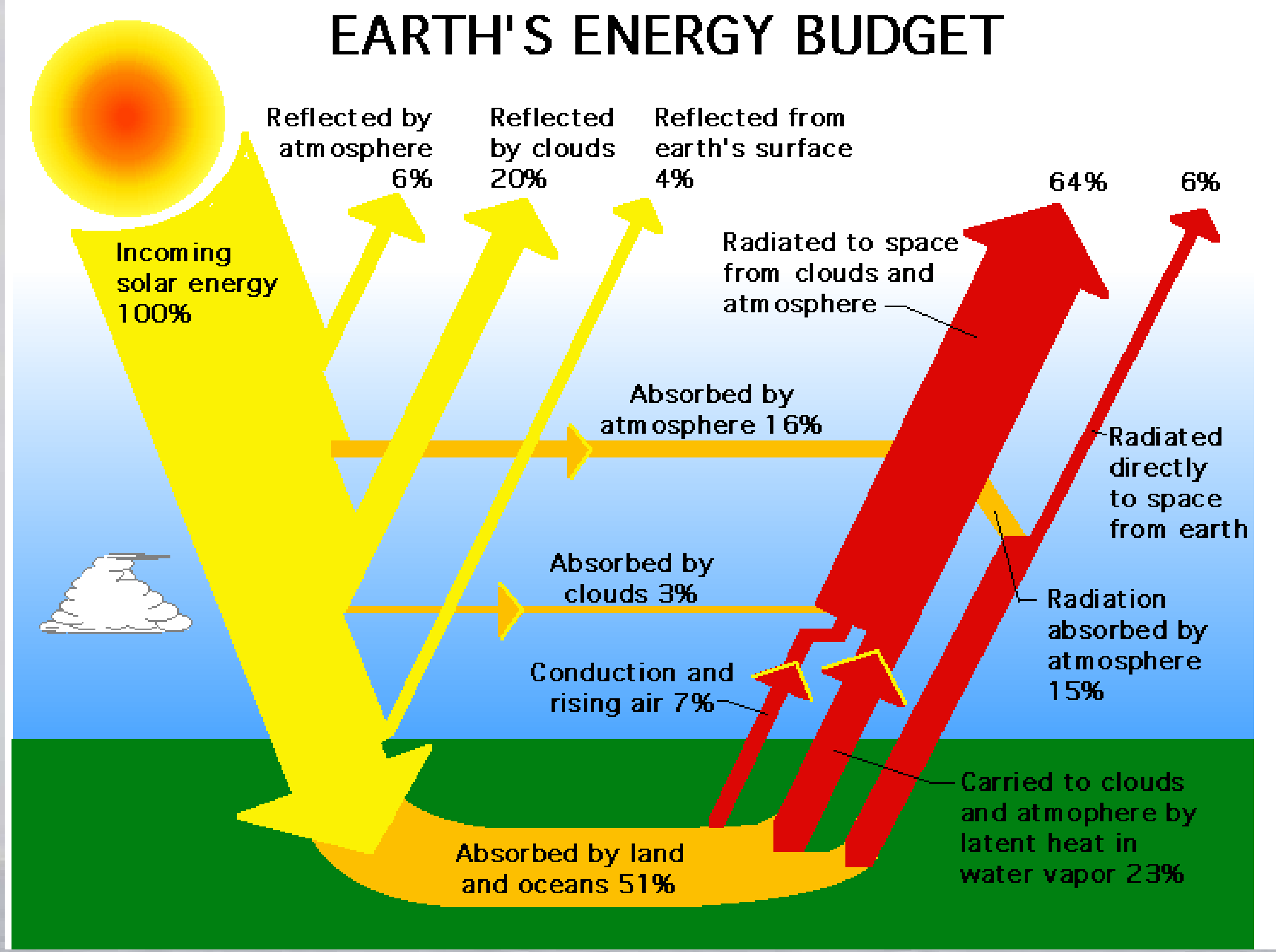
Basic parameters: Temperature

- **How can the Air Temperature be changed ?**
  - **1. Diabatic Heating - Radiation**





Basic parameters: Temperature



- **Solar Input / Solar constant**

$$E_0 = 1367\ \frac{\mathrm{W}}{\mathrm{m}^2} = 1367\ \frac{\mathrm{J}}{\mathrm{m}^2\,\mathrm{s}} = 1367\ \frac{\mathrm{kg}}{\mathrm{s}^3}$$

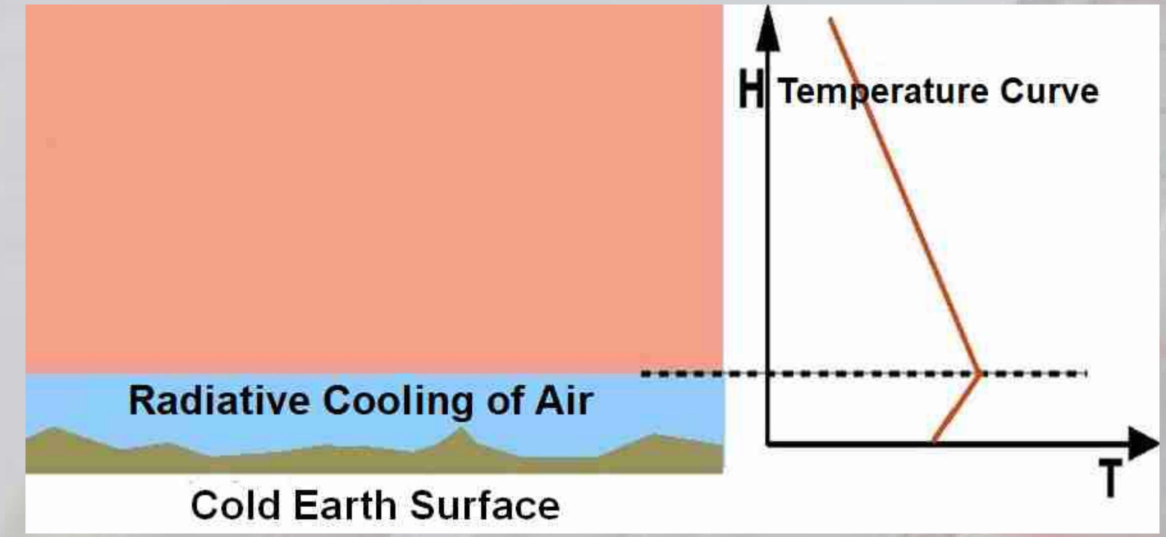
- **Upper atmosphere**
- **1.367 W/m**2 170 000 GW Earth**
- **Reflected (Albedo) 30 %**
- **At Surface**
- **~ 150-300 W/m**2**
- **~ 3.7 – 7.0 kWh/m**2**

VERTICAL STRUCTURE OF THE ATMOSPHERE: INVERSIONS

How can the Air Temperature be changed ?

How does this change the Vertical Temperature Profile ?

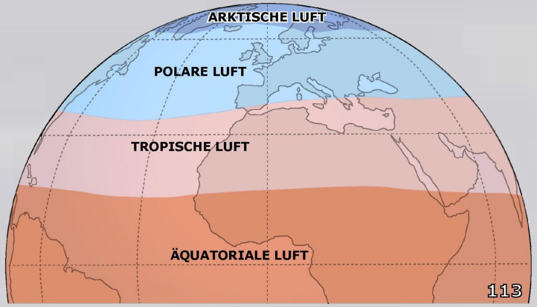
1. Radiative Heating / Cooling



Radiative inversion

Cooling due to outgoing IR-radiation (sky clear / few clouds conditions)

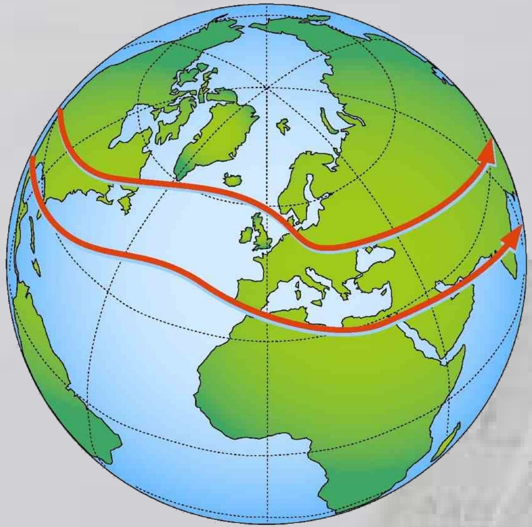
BASIC PARAMETERS: TEMPERATURE

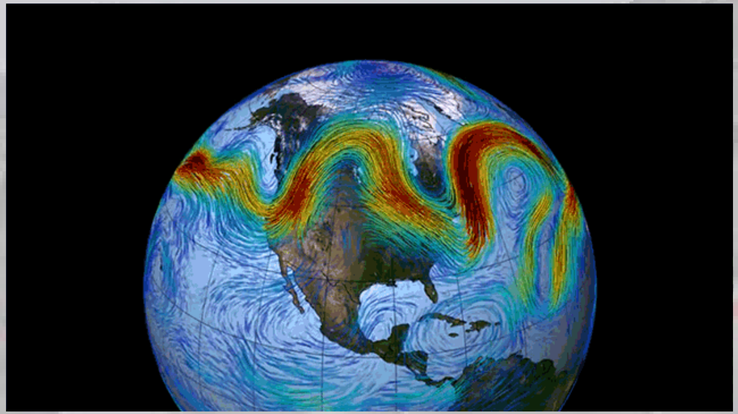


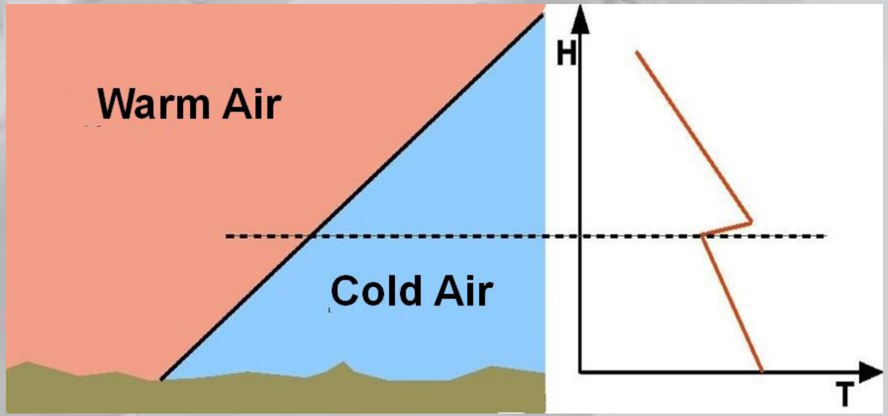
How can the Air Temperature be changed ?

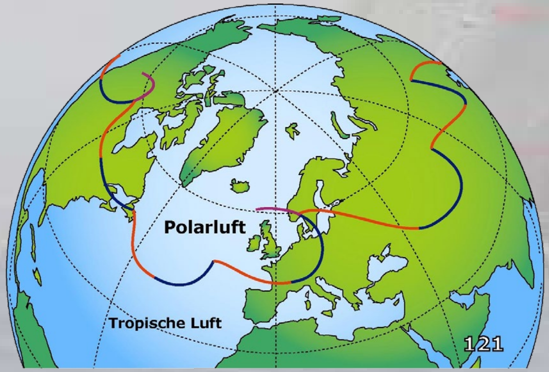
How does this change the Vertical Temperature Profile ?

2. Cold / Warm Air Advection









Global Circulation

Jetstream

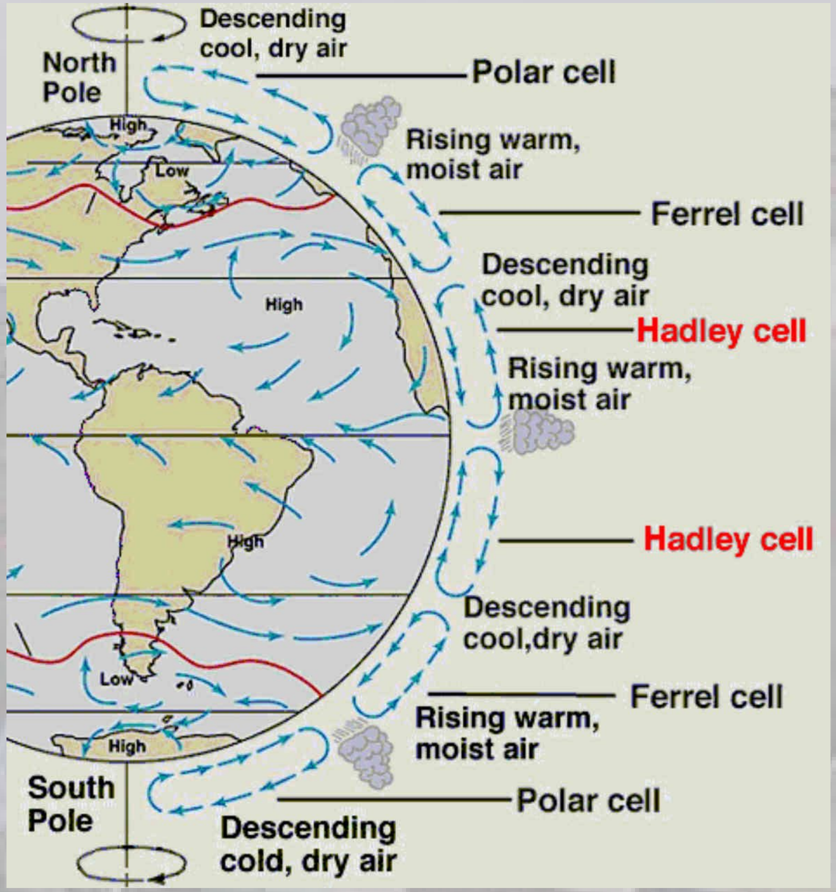
Upslide inversion

Upslide motion of warm air (warmfront)

Basic parameters: Temperature

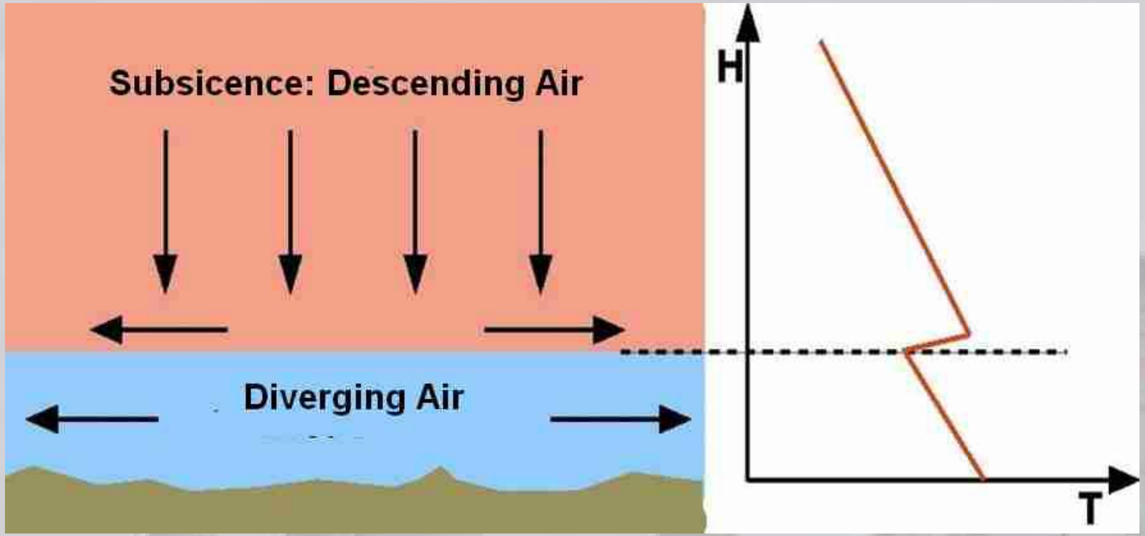
- How can the Air Temperature be changed ?

  3. Pressure Change Subsidence / Lifting



VERTICAL STRUCTURE OF THE ATMOSPHERE: INVERSIONS

3. Adiabatic Compression / Expansion



Subsidence inversion

Subsidence in a High (warming to compression of air like in air pump)

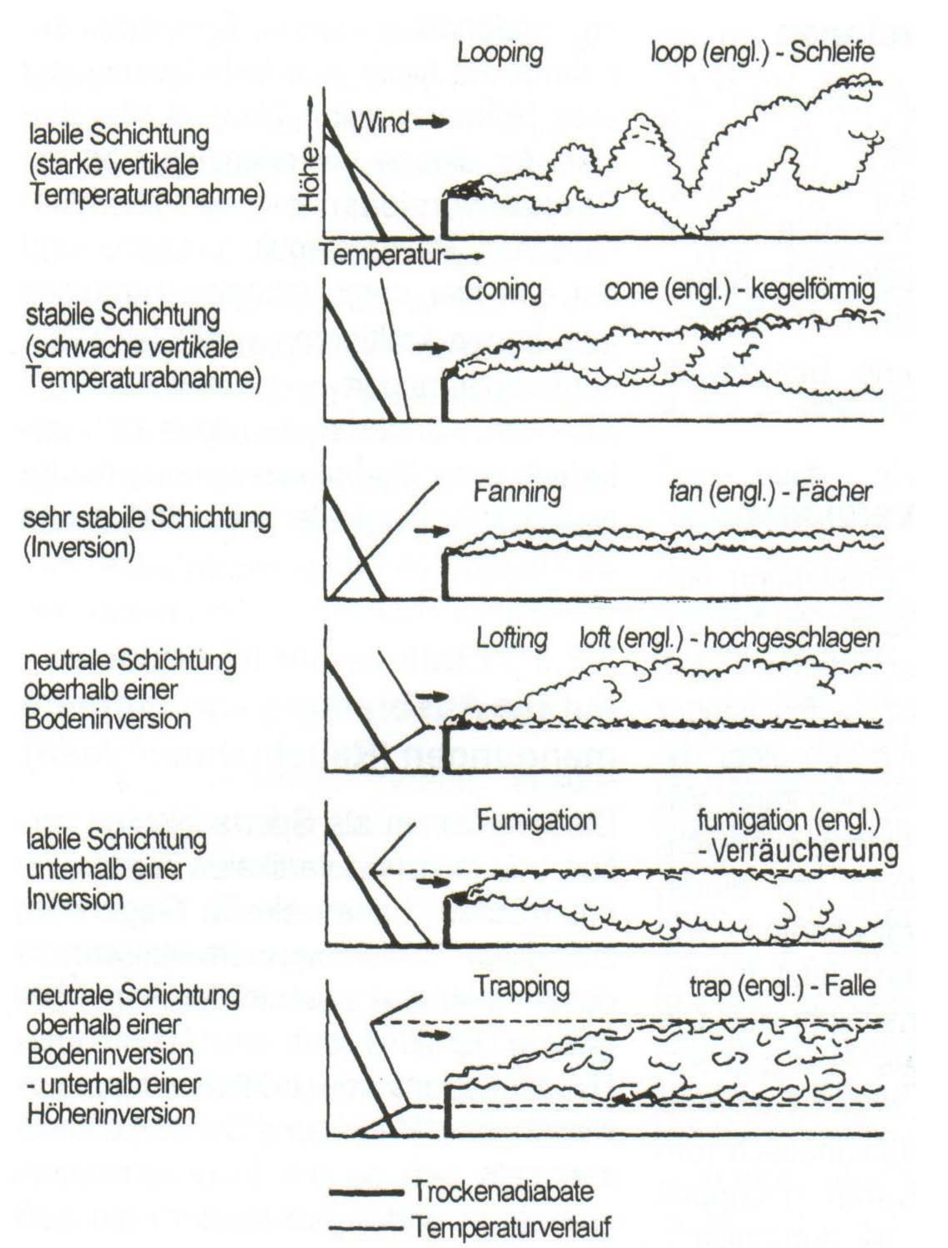
Atlantic Trade wind inversion

High pressure situation in winter low-exchange weather condition
Smog below inversion

High pressure situation in general

In the mountains:
Valley situation: overcast
Summit situation: sky clear

STABILITY, INVERSIONS AND PLUMES



Looping

Unstable, vertical temperature gradient > 1°/100m

Coning

Stable, vertical temperature gradient < 1°/100m

Fanning

Very stable, high inversion

Lofting

Indifferent stratification, above inversion

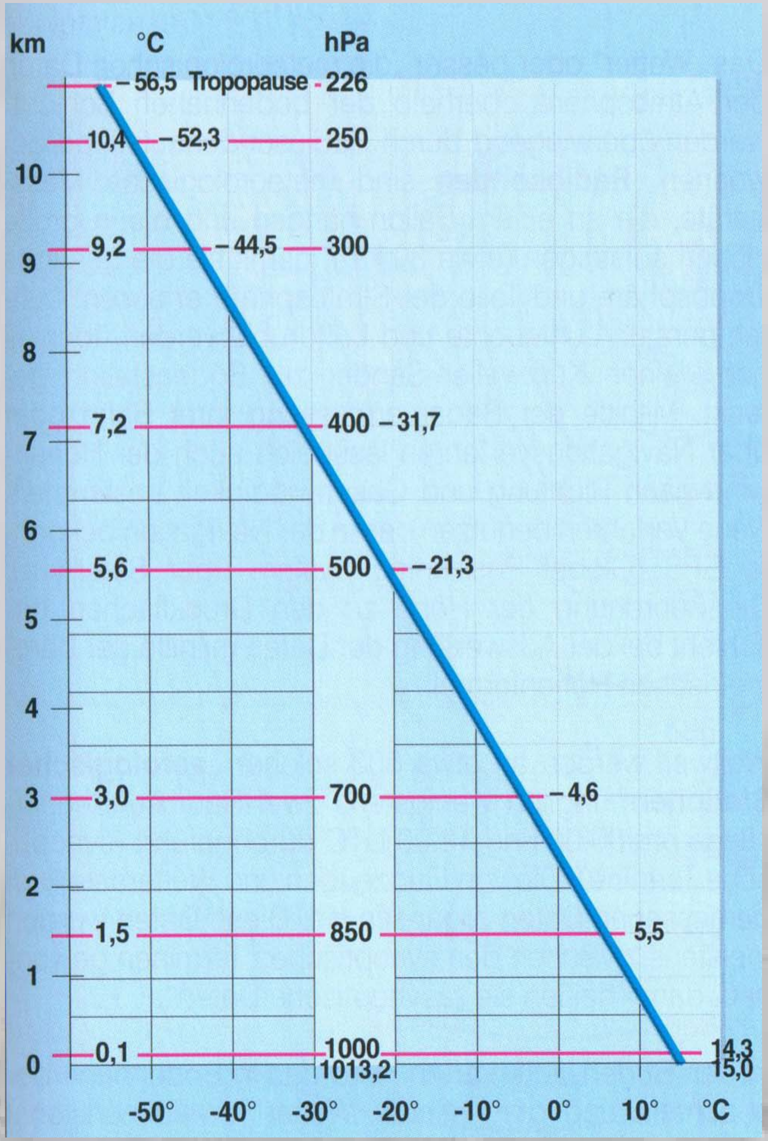
Fumigation

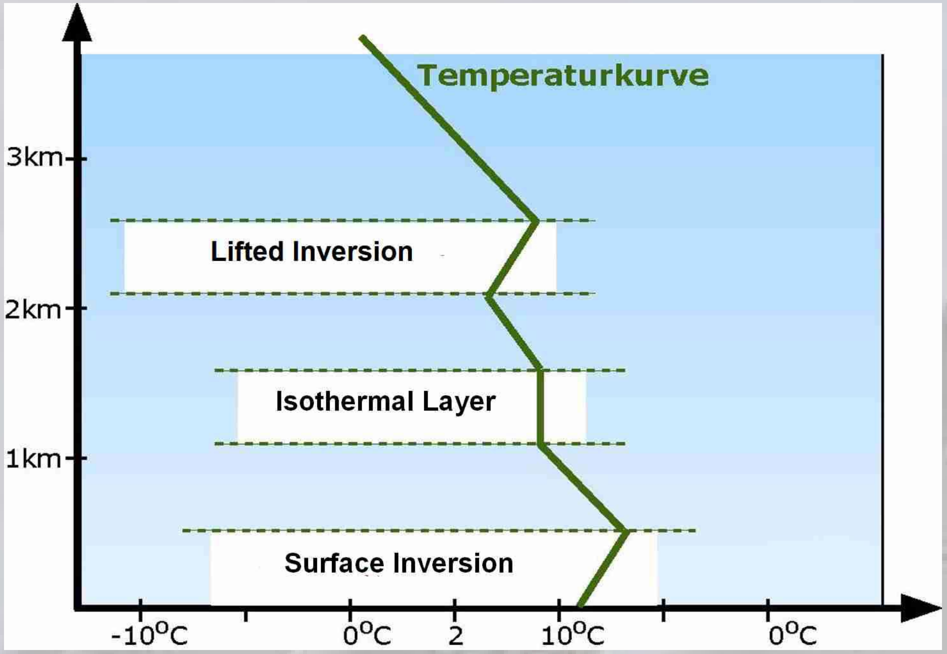
Unstable, below inversion

Trapping

Between two inversions

VERTICAL STRUCTURE OF THE ATMOSPHERE: INVERSIONS





Temperature Inversion

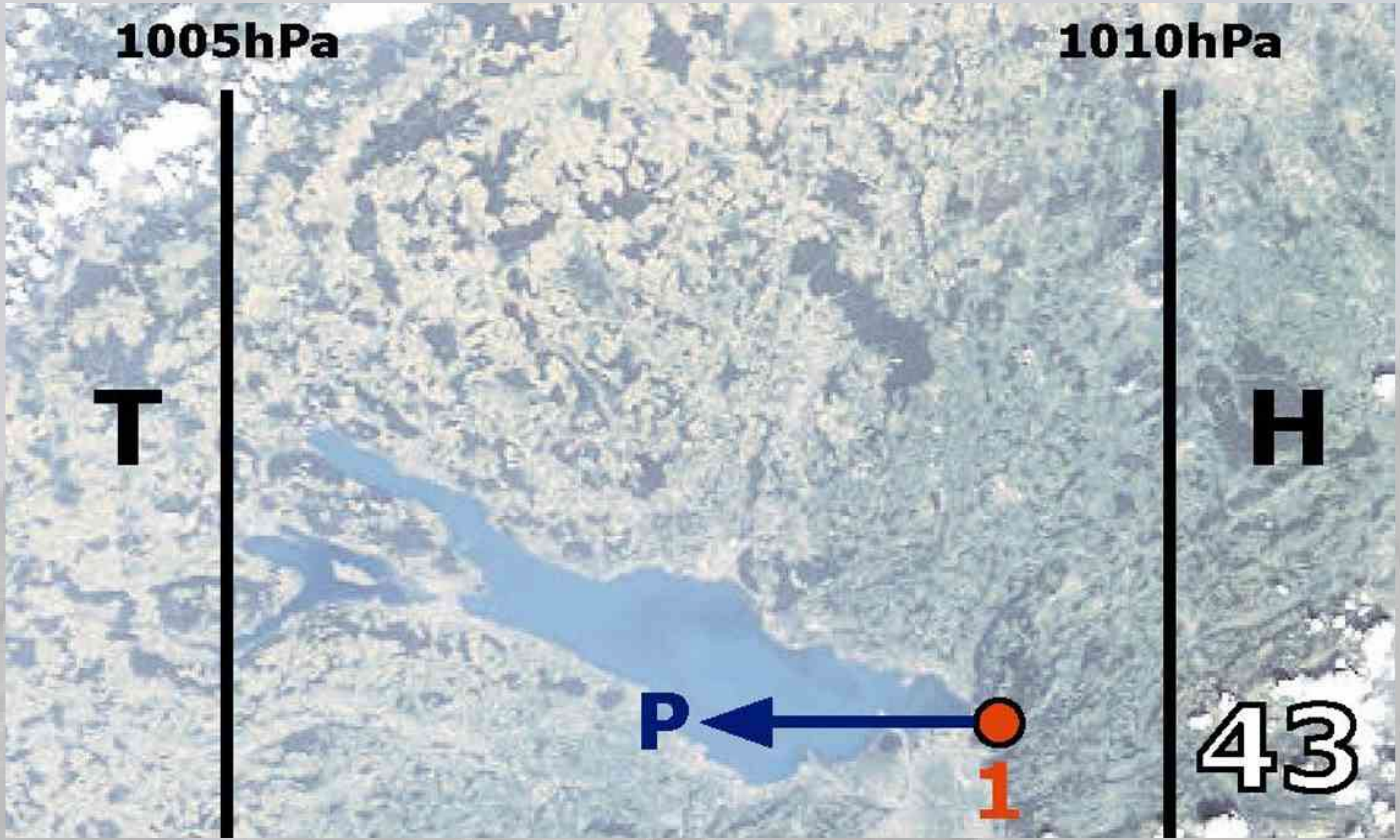
instead of T-decrease with height

sometimes T-increase with height

Inversions are vertically impermeable

(e.g. low-exchange weather condition)

BASIC PARAMETERS: GEOSTROPHIC WIND



Pressure differences cause a force…………………….. pressure gradient force PGF
As soon as the air particles are pushed by the PGF
to lower pressure, they are deflected by the....…….... Coriolis force

Coriolis Force ...

- … **is proportional to the velocity**
  IF velocity = 0 **THEN** Coriolis Force = 0 (same as rudder force)

- … **increases with latitude**
  Coriolisparameter = 2 * 360° / 86164 * sin(Breite) = 10^{-4} sec^{-1}

- … **acts perpendicular to the direction of motion**

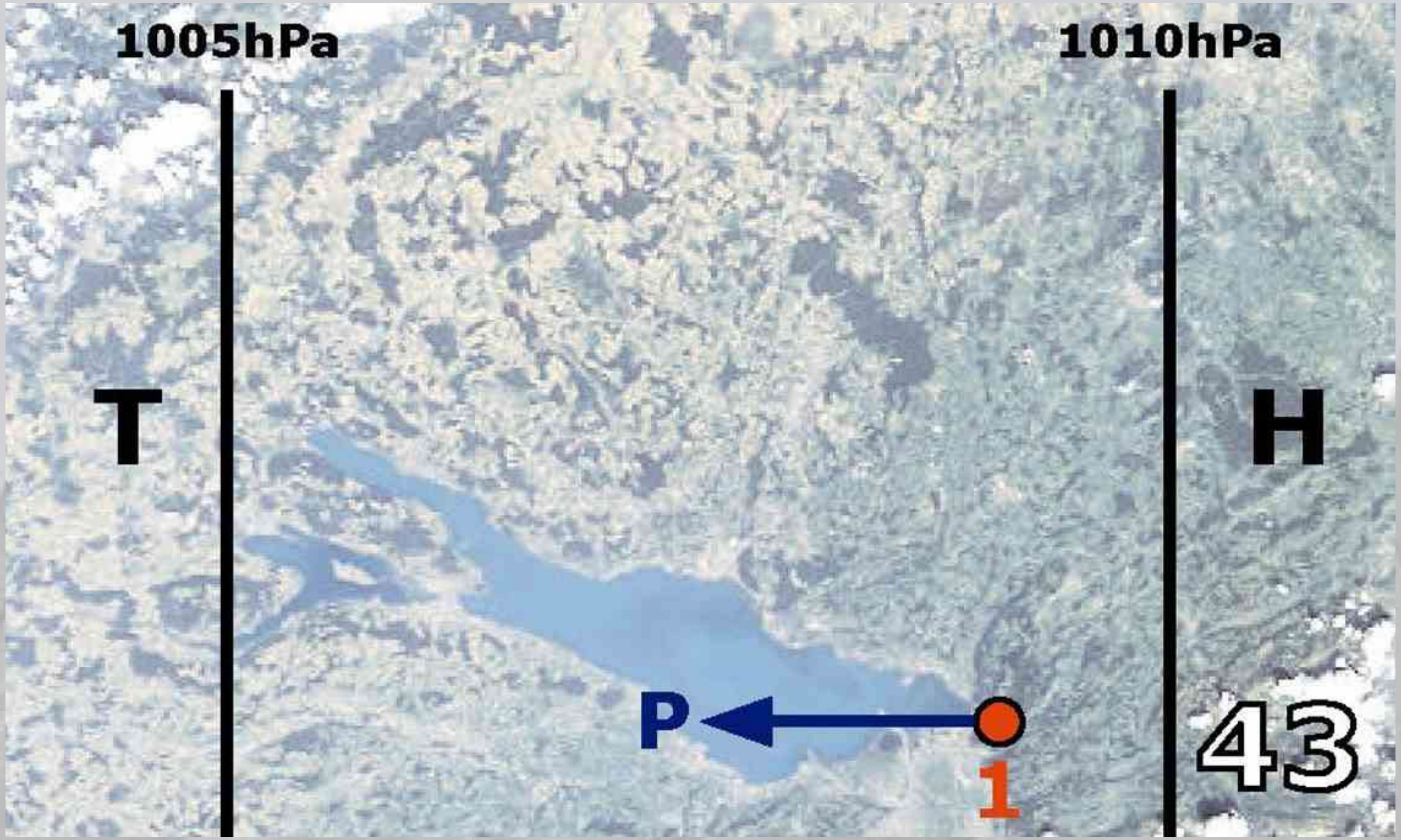
  Pseudo (fictitious) Force — does not perform physical work
  Northern- / Southern Hemisphere — deflects air particles to the right / left

  Veering of the wind with increasing height (boundary layer only)
  Decreasing friction ⇔ Increasing windspeed

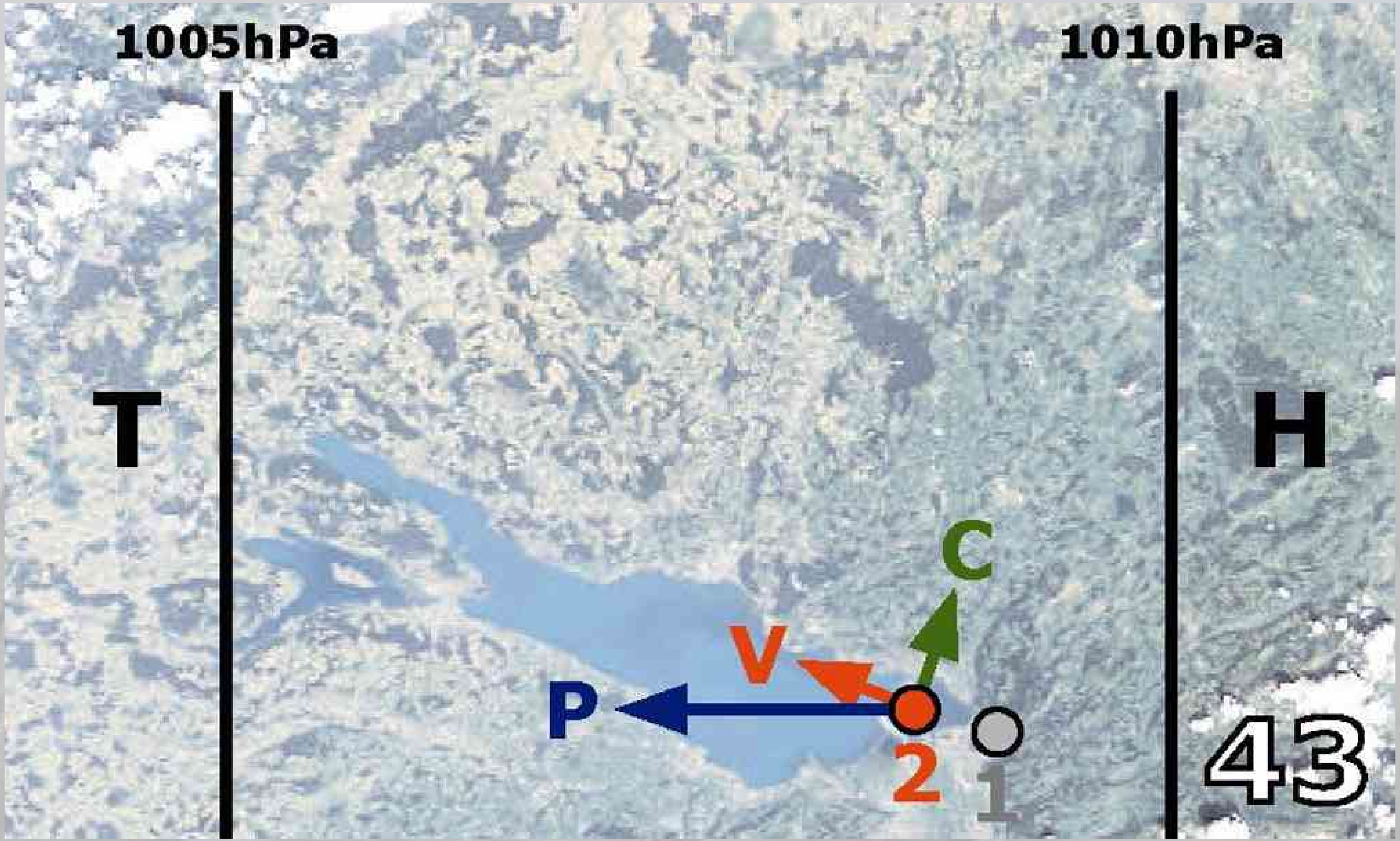
- … **Determines the direction of rotation of Lows and Highs**

  Northern (Southern) Hemisphere : Low: counterclockwise (clockwise)
  Hoch: clockwise (counterclockwise)

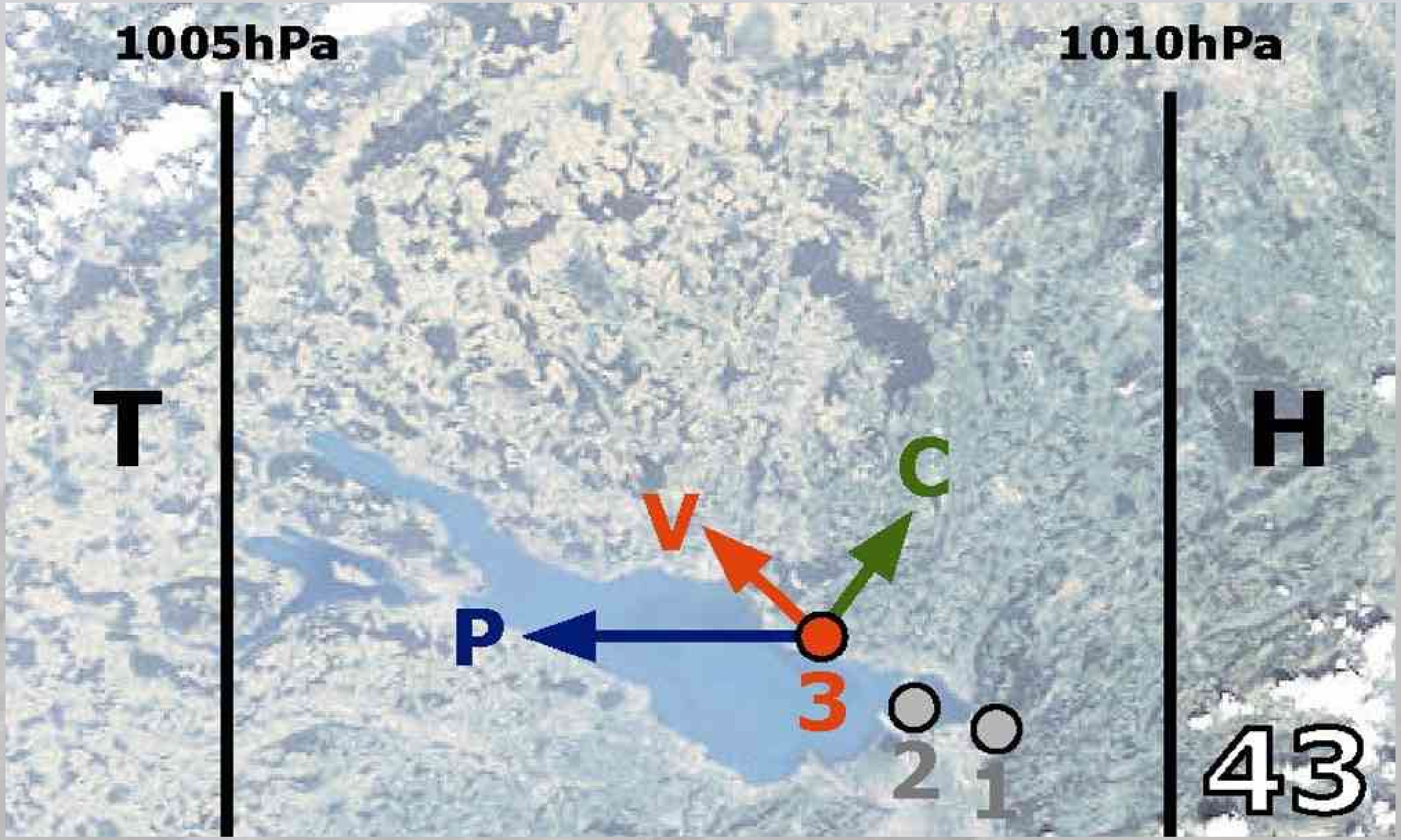
GEOSTROPHIC WIND



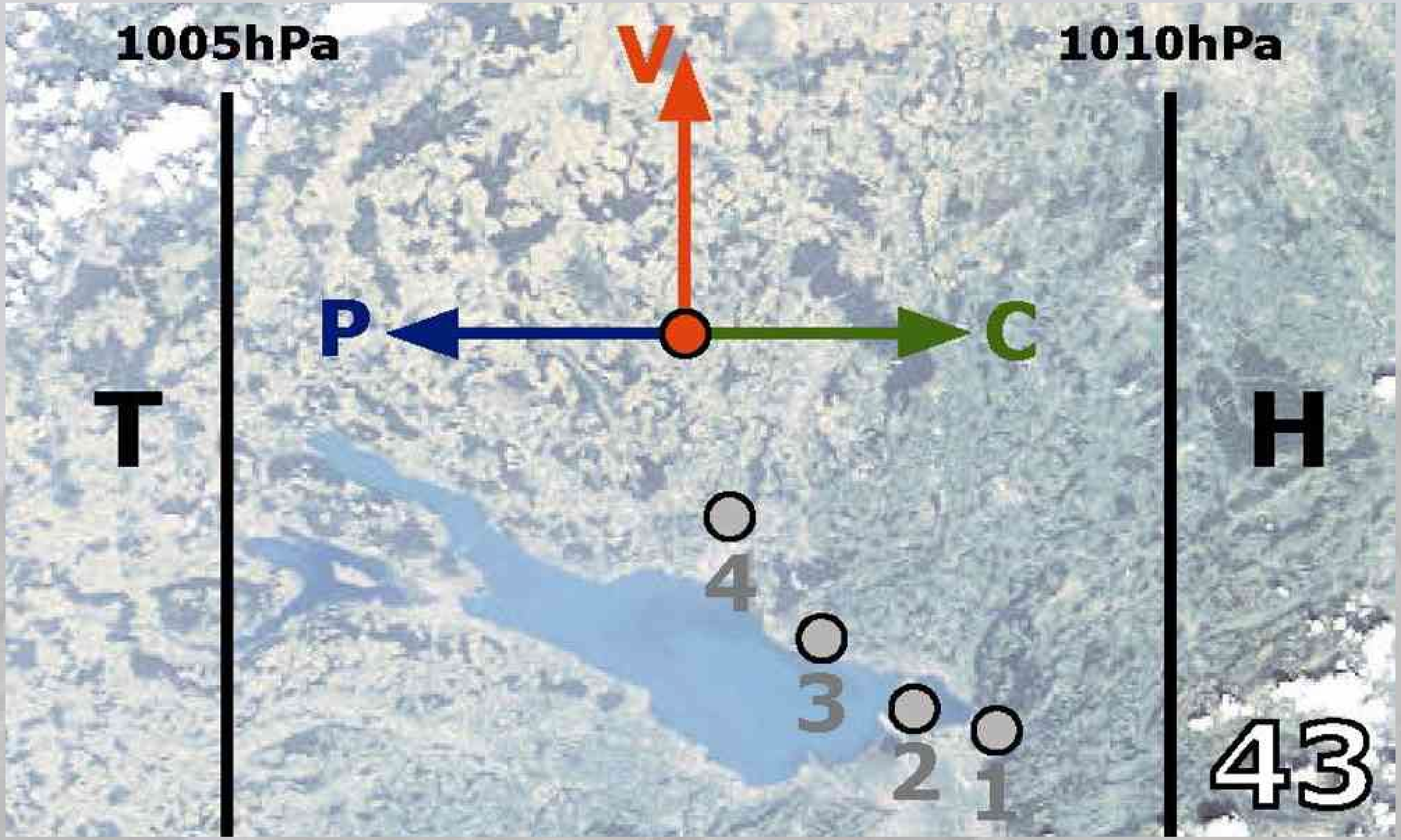
GEOSTROPHIC WIND



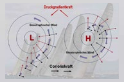
GEOSTROPHIC WIND

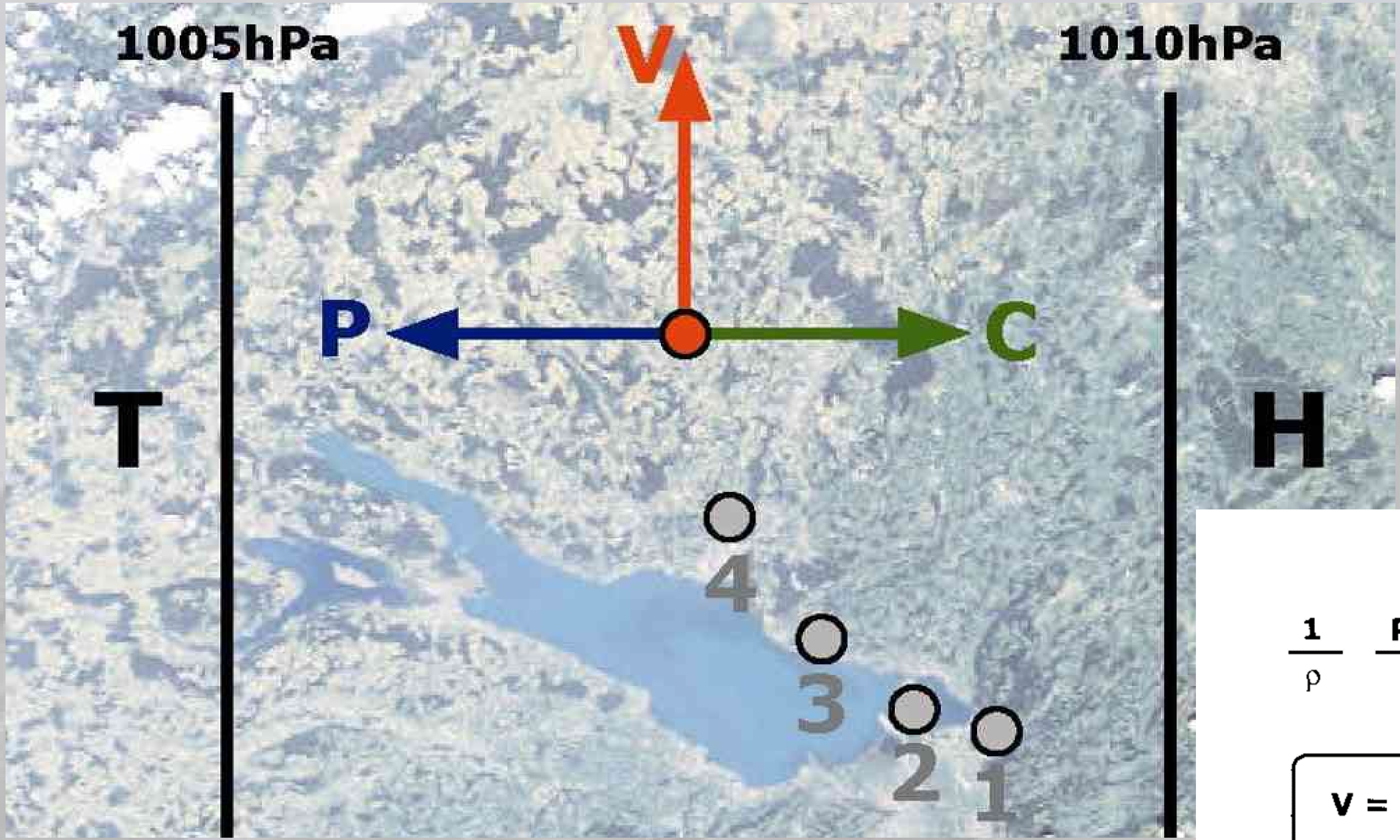


Geostrophic wind



GEOSTROPHIC WIND





$$P = C$$

$$\frac{1}{\rho} \, \frac{P_1 - P_2}{L} = 2\, V\, \omega \sin \varphi$$

$$V = \frac{1}{2\, \omega\, \rho \sin \varphi} \, \frac{P_1 - P_2}{L}$$

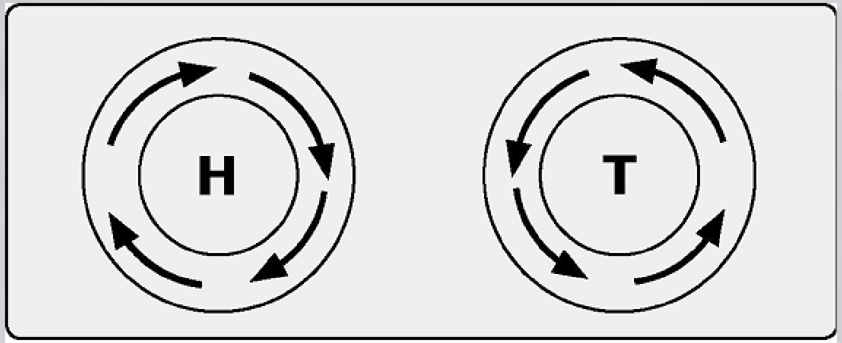
ω (omega) = Earth's Angular Velocity

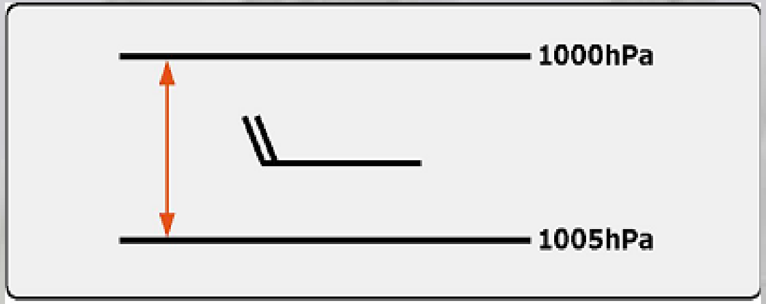
φ (phi) = Latitude

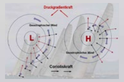
ρ (rho) = Air Density

- Coriolis parameter = 2 * 360° / 86164 * sin(lat) = 10^{-4} sec^{-1}
- 24 Std sidereal day !

GEOSTROPHIC WIND



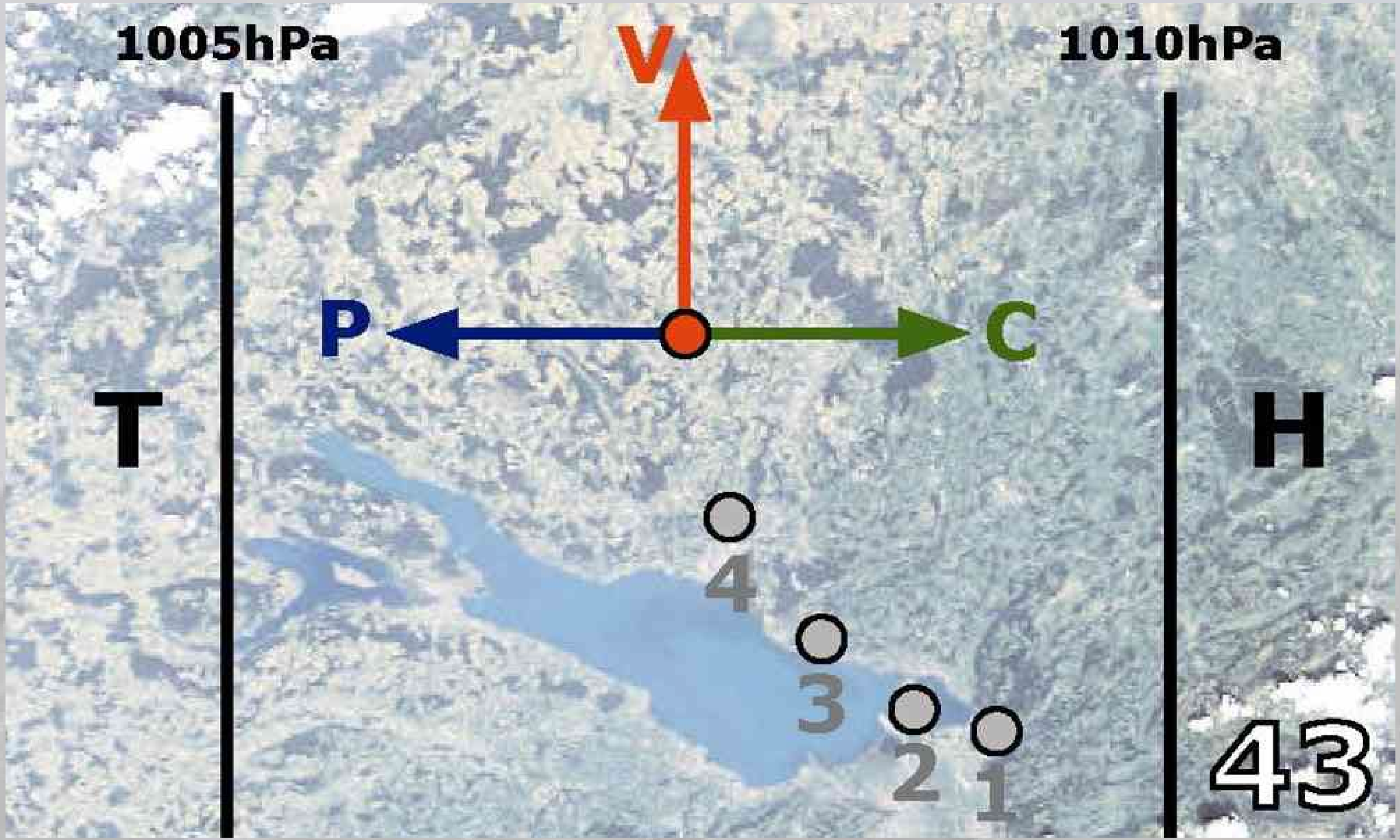




Geostrophic Wind …

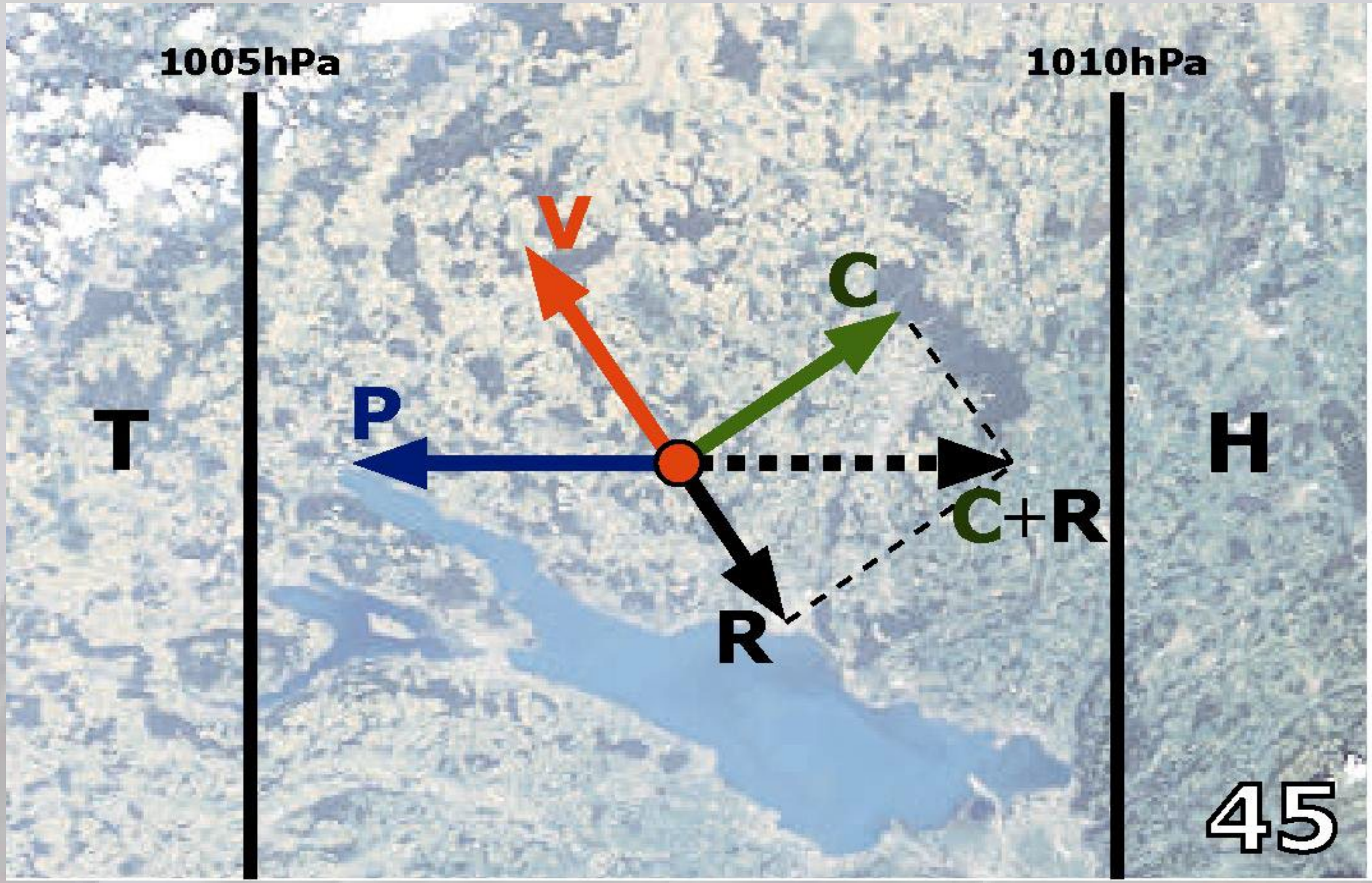
- … is the equilibrium between pressure gradient force and Coriolis force.
- … blows parallel to the isobars
- … has a speed that results from the
  - distance between the isobars
  - the latitude
- … blows clockwise around anti-cyclones and counterclockwise around cyclones
- … Friction results in ageostrophic components directed towards the low and away from the highs thus reducing pressure gradients.

GEOSTROPHIC WIND



… but: near the surface, friction plays an important role!

GEOSTROPHIC WIND WITH FRICTION

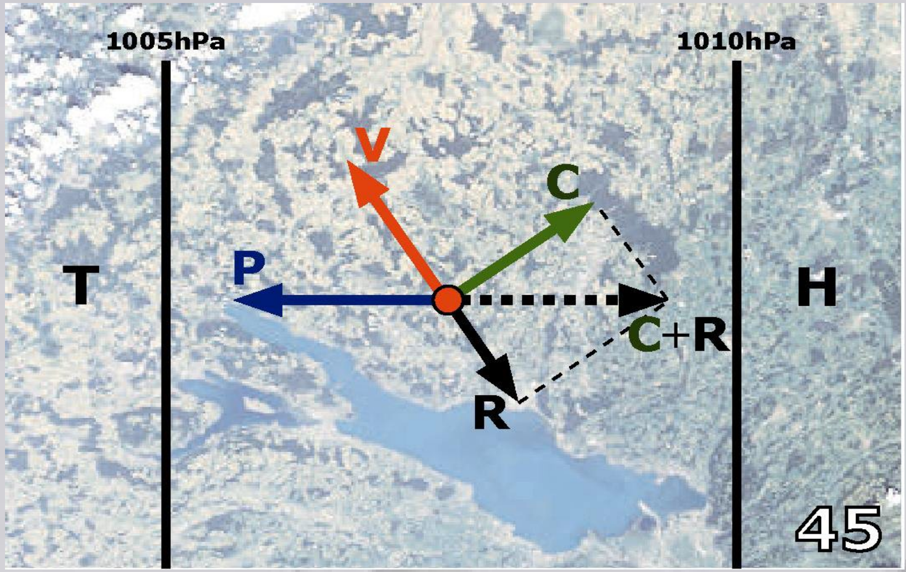


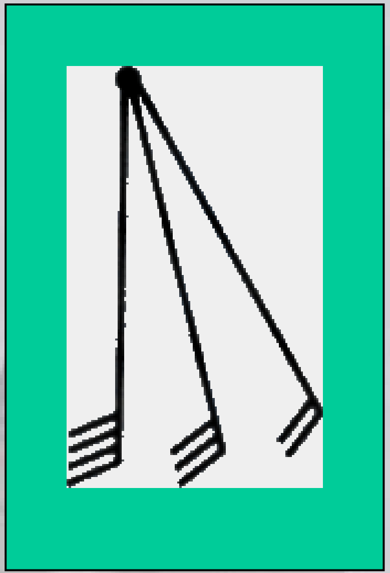
Friction reduces the windspeed – consequences:

- **Coriolis force is reduced**
- **Deflection to the right (NH) decreases, which means:**
- **Deflection to the left (NH), towards lower pressure**

Friction thus fills lows and weakens highs

GEOSTROPHIC WIND WITH FRICTION



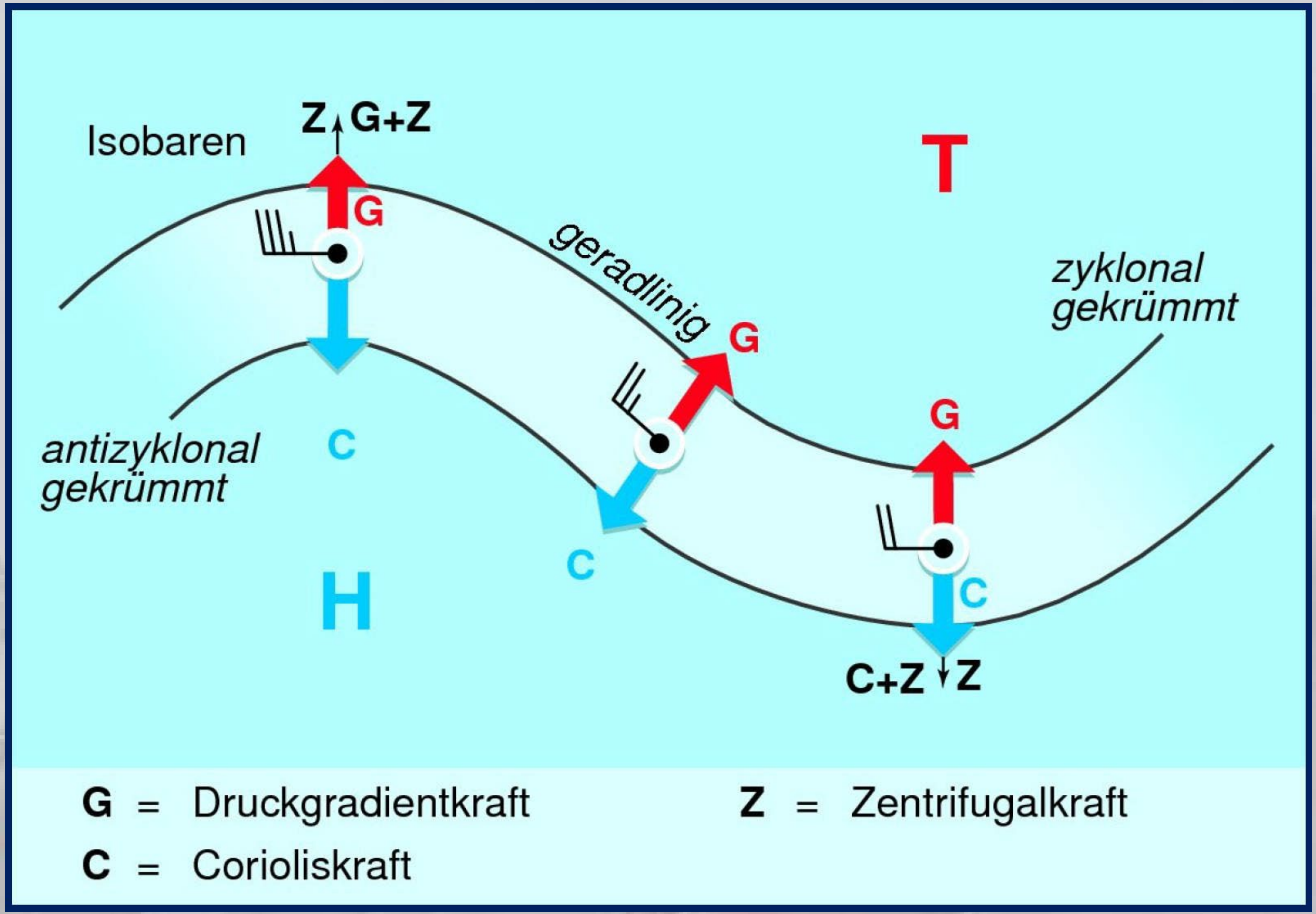


boundary layer: friction effects decrease with height
accordingly: increase of windspeed with height
NHK: veering of wind to the right (NH)

Difference between surface wind and geostrophic wind due to friction

Over sea:	direction	about 20° (towards low)	velocity reduction	20 to 30 %
Over land:		about 40° (towards low)		30 to 50 %

GRADIENT WIND



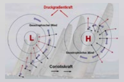
Centrifugal force with …

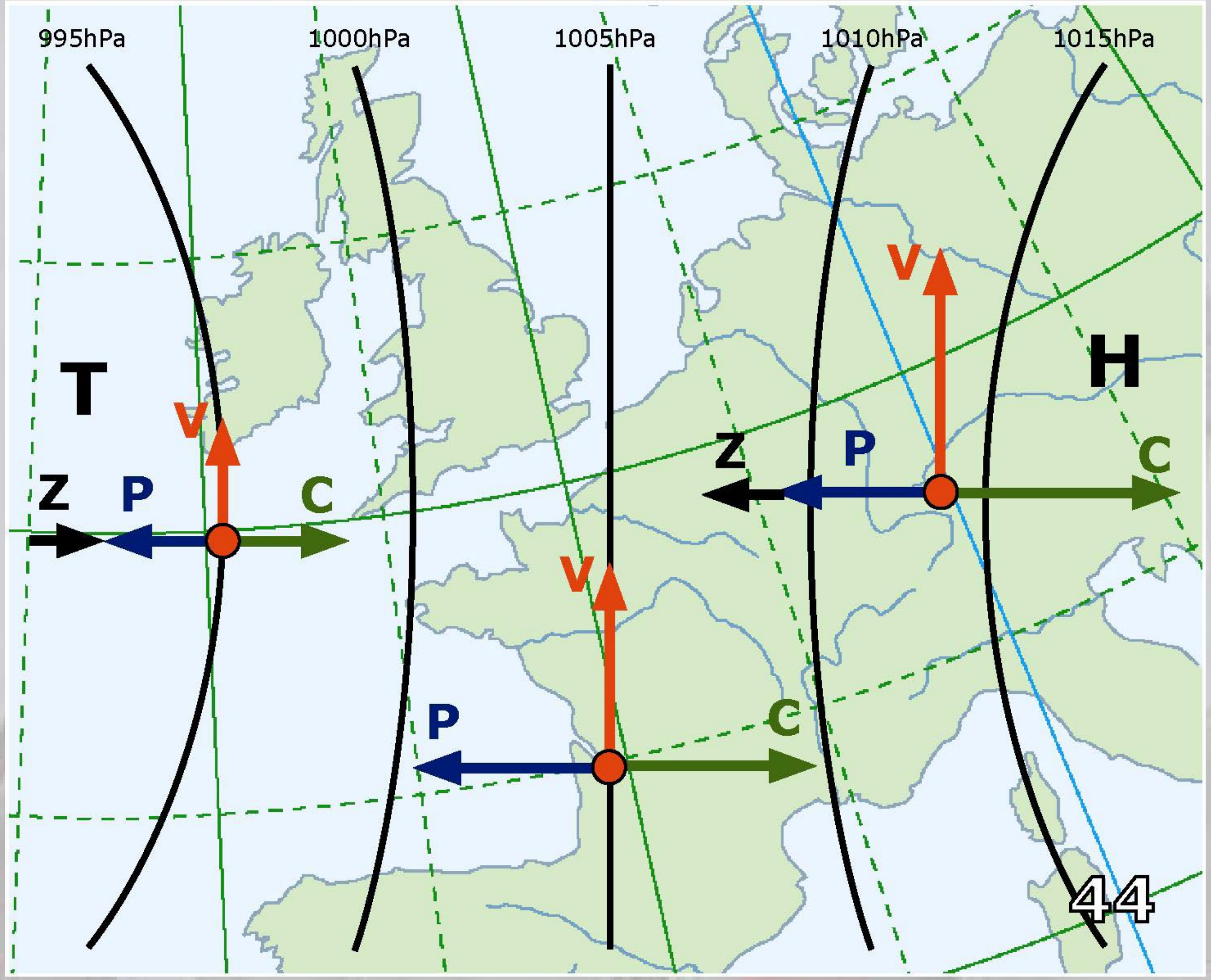
… cyclonic curvature decreases the pressure gradient force

… anti-cyclonic curvature increases the pressure gradient force

Supergeostrophic wind in the vicinity of anti-cyclones !

Gradient wind





High: Wind is stronger than to be expected from the isobars: supergeostrophic, between 1-2 Bft.

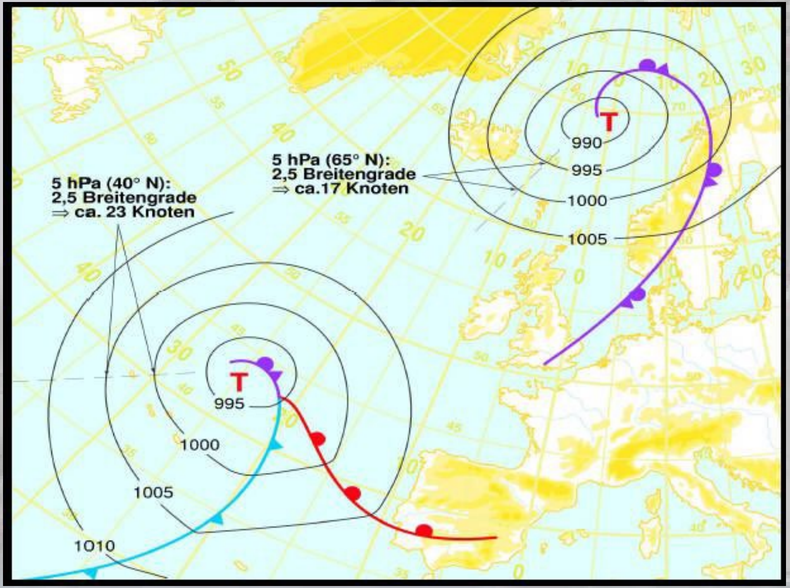
Low: Wind is weaker than to be expected from the isobars (curvature)

CORIOLIS FORCE AS FUNCTION OF LATITUDE

- **Coriolis parameter = 2 * 360° / 86164 * sin(latitude) = 10^{-4} sec^{-1}**
  - **24 Std sidereal day**

- **= 0 at the equator, increasing with latitude**

- **As the geostrophic wind describes the equilibrium between pressure gradient force and Coriolis force, the same windspeed requires a stronger pressure gradient at higher latitudes.**

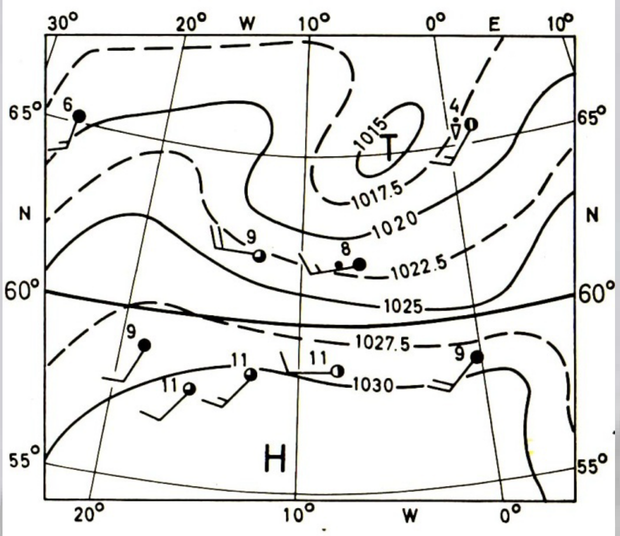


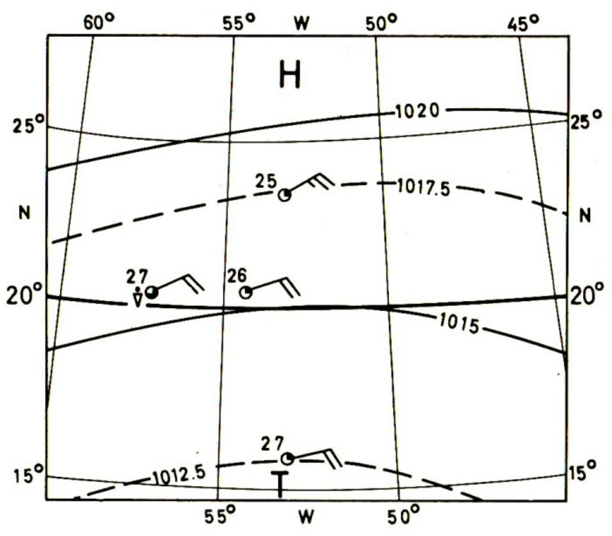
Interpretation of wind from weather chart

First guess: the more isobars, the higher the windspeed.

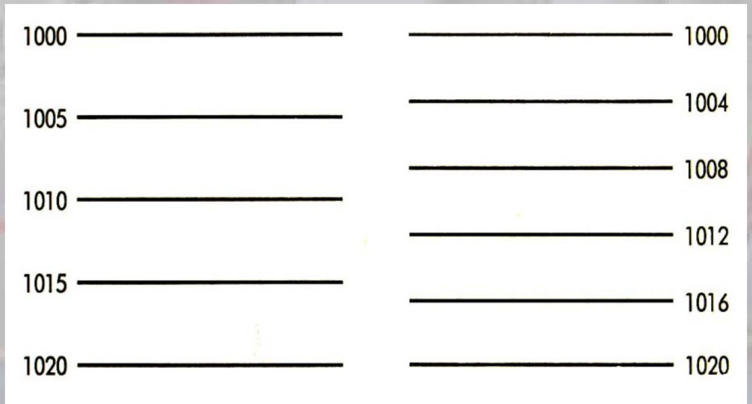
Basically yes, but …

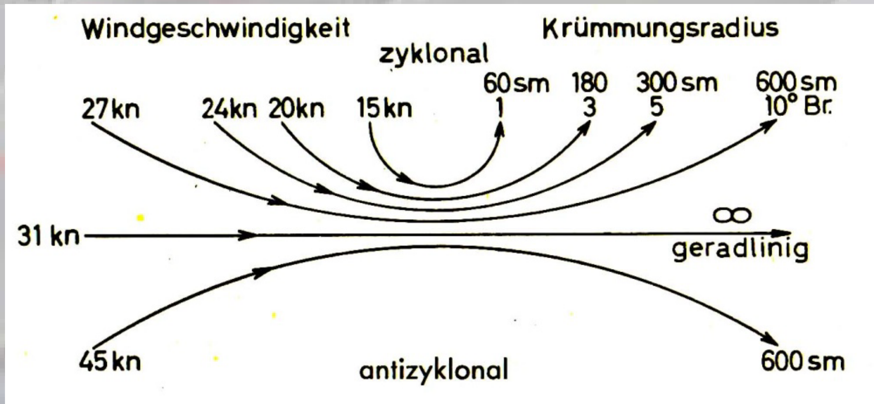
60°N





20°N

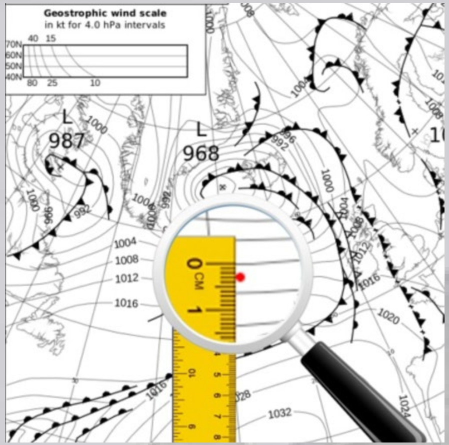


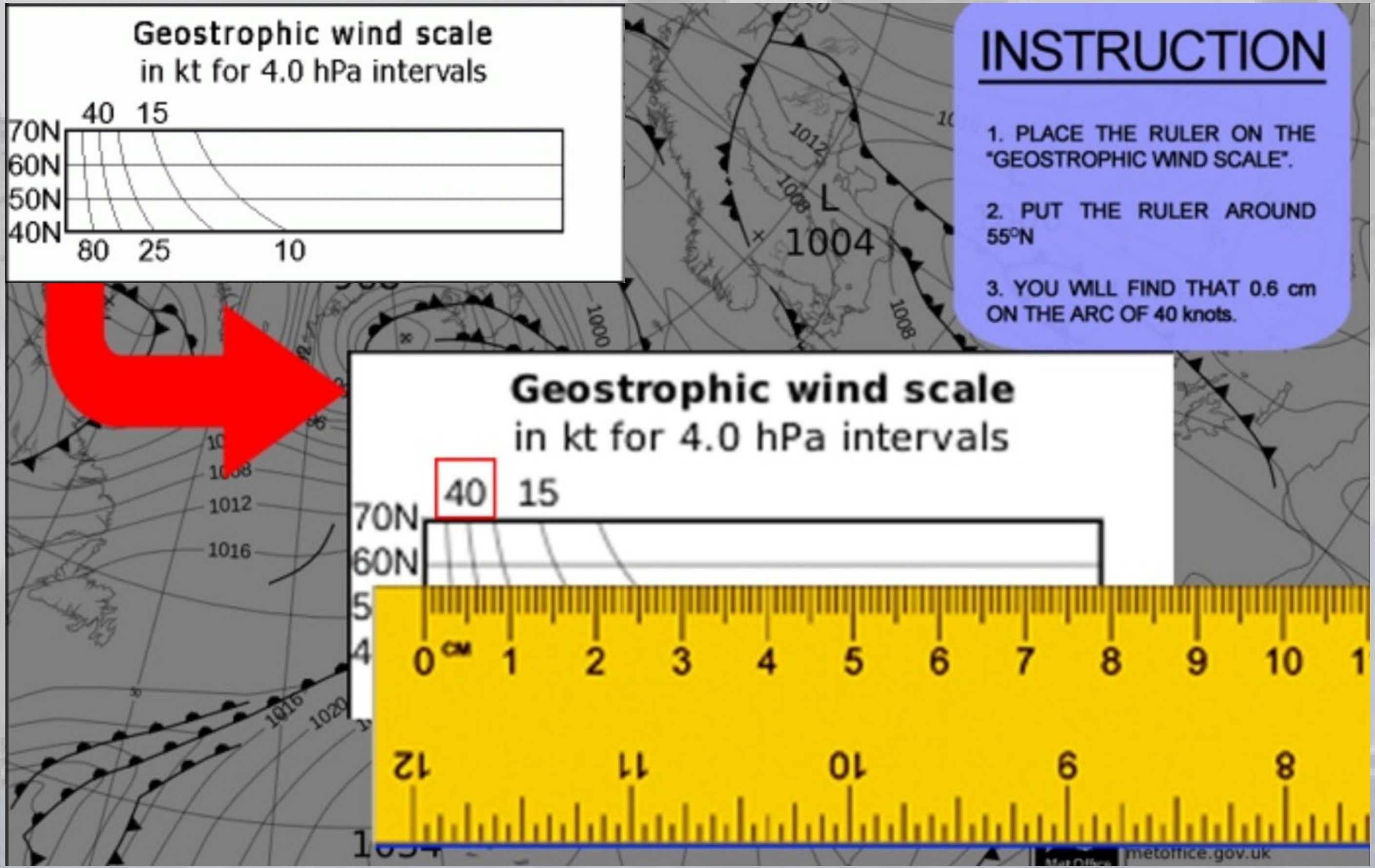


WIND DETERMINATION: GEOSTROPHIC WIND SCALE

Important:

Latitude	
Isobaric increment	**4-4 or 5-5 hPa**
Isobaric gradient	**at ship's position**
Friction effect reduction	**20-30 %**





BEAUFORT SCALE: WIND SPEED

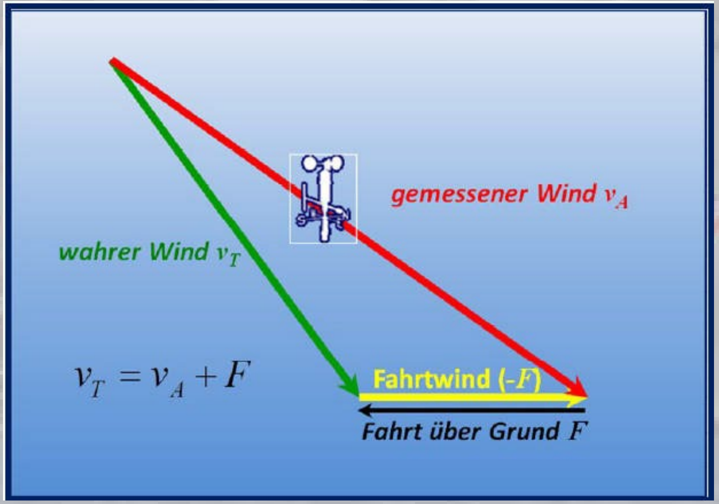
Beaufort-grad	m/s	km/h	m. p. h.	Knoten	Staudruck in kg/m²
0	0 — 0,2	1	1	1	0
1	0,3— 1,5	1— 5	1— 3	1— 3	0— 0,1
2	1,6— 3,3	6— 11	4— 7	4— 6	0,2— 0,6
3	3,4— 5,4	12— 19	8—12	7—10	0,7— 1,8
4	5,5— 7,9	20— 28	13—18	11—15	1,9— 3,9
5	8,0—10,7	29— 38	19—24	16—21	4,0— 7,2
6	10,8—13,8	39— 49	25—31	22—27	7,3—11,9
7	13,9—17,1	50— 61	32—38	28—33	12,0—18,3
8	17,2—20,7	62— 74	39—46	34—40	18,4—26,8
9	20,8—24,4	75— 88	47—54	41—47	26,9—37,7
10	24,5—28,4	89—102	55—63	48—55	37,4—50,5
11	28,5—32,6	103—117	64—72	56—63	50,6—66,5
12	32,7 und mehr	118 und mehr	73 und mehr	64 und mehr	66,6 und mehr

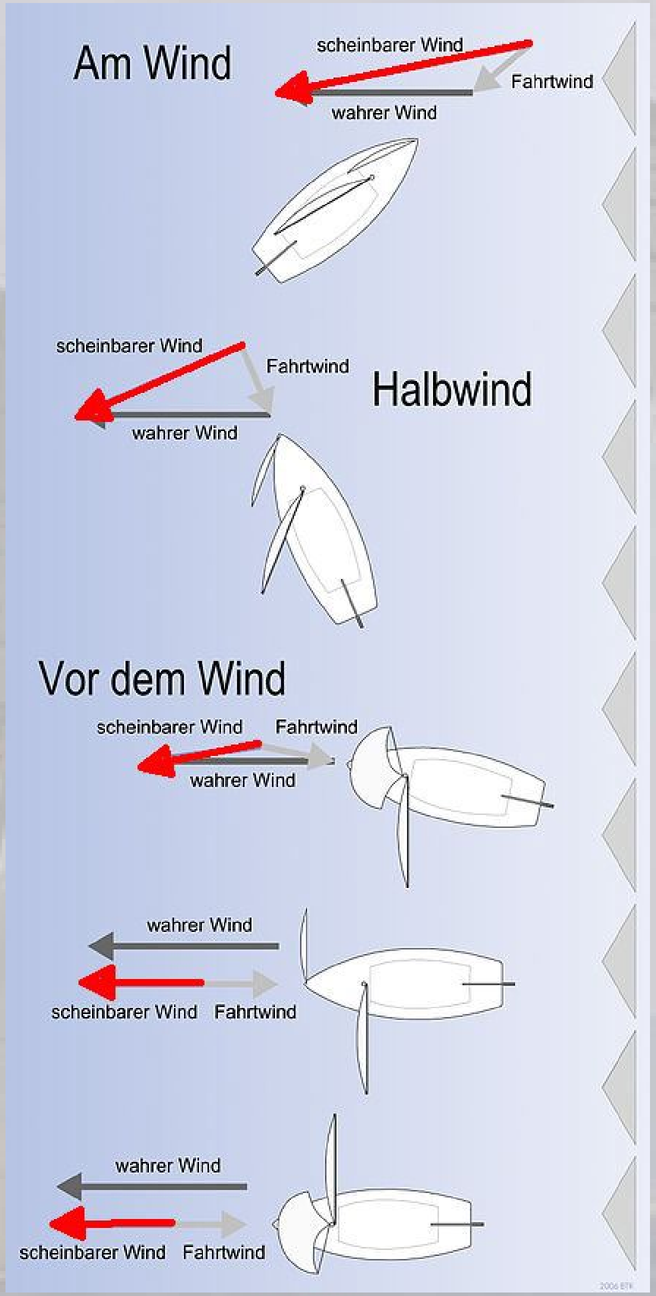
BEAUFORT SCALE: WIND SPEED

Beaufort-grad	m/s	km/h	m. p. h.	Knoten	Staudruck in kg/m²
0	0				
1	0,3	1	1	1	0
2	1,6	6	4	4	0,2
3	3,4	12	8	7	0,7
4	5,5	20	13	11	1,9
5	8,0	29	19	16	4,0
6	10,8	39	25	22	7,3
7	13,9	50	32	28	12,0
8	17,2	62	39	34	18,4
9	20,8	75	47	41	26,9
10	24,5	89	55	48	37,4
11	28,5	103	64	56	50,6
12	32,7 und mehr	118 und mehr	73 und mehr	64 und mehr	66,6 und mehr

Apparent wind

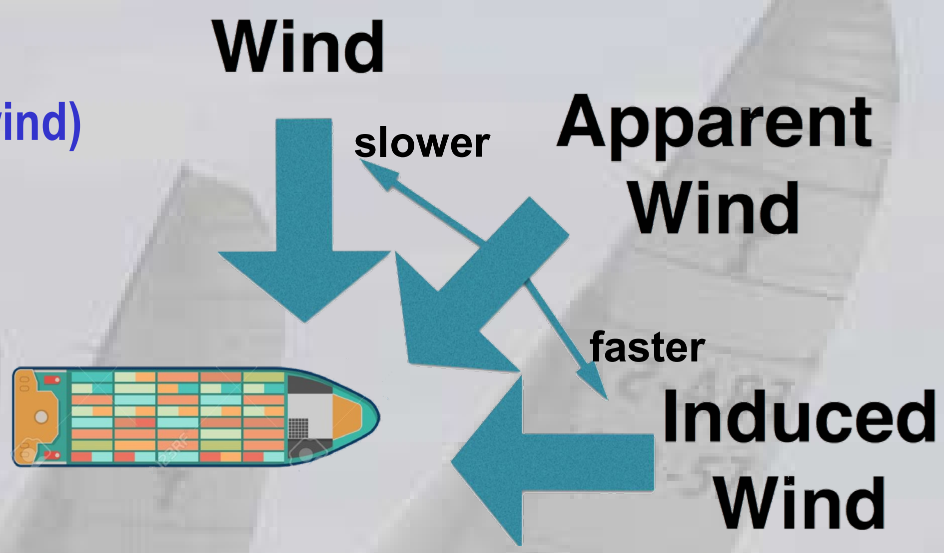
- Vector sum of true wind and induced wind
- Caused by ship‘s velocity above ground
- The wind measured on board (Verklicker)
- Comes from further forward than the true wind
- Sailships use the apparent wind
- Sail setting follows the apparent wind



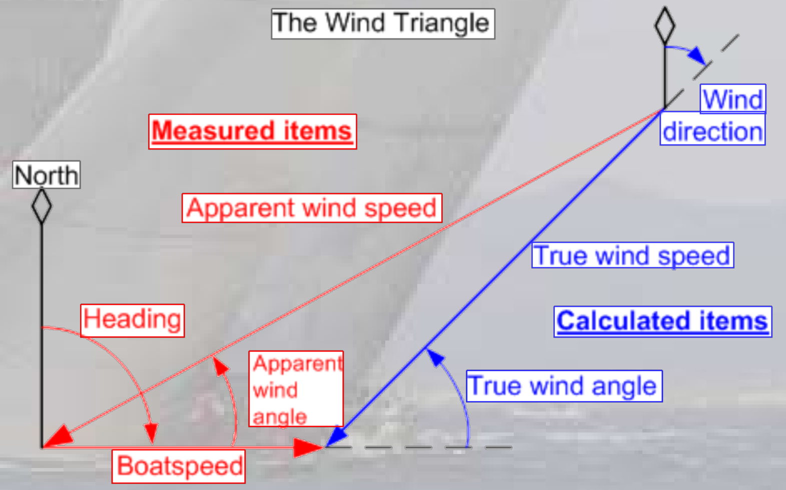


Apparent wind …

- … is the wind measured on board (wind vane)
- … is caused by ship‘s speed over ground (induced wind)
- … is the vector sum of true wind and induced wind
- … comes from further forward than the true wind
- … is used by sailships for sail setting



- Measured items as INPUT for ship‘s computer:
  - ship‘s speed, apparent wind angle / ~speed
- Computed items as OUTPUT of ship‘s computer:
  - true wind direction, true wind speed

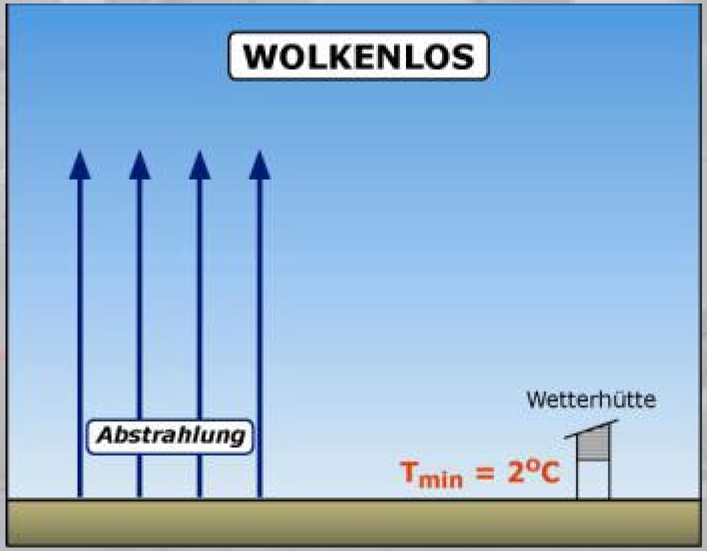


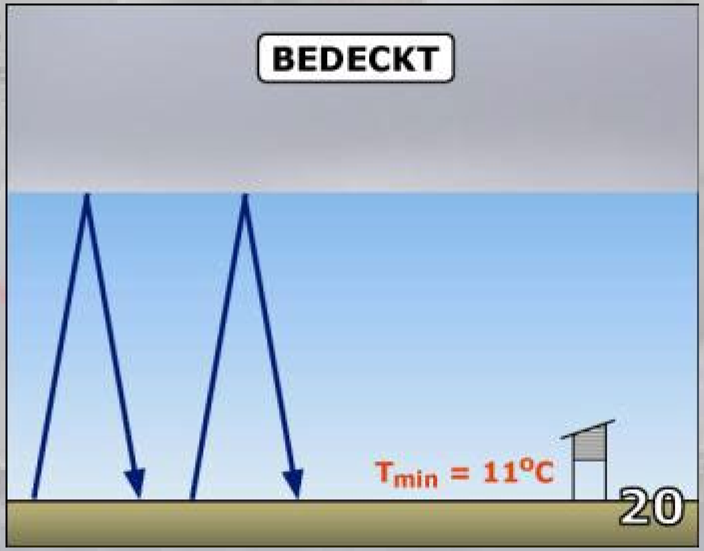
BASIC PARAMETERS: HUMIDITY

Properties of water in the atmosphere

Water vapor : invisible gas. In the atmosphere, it is the most important constituent with respect to thermodynamics: 0% < volume fraction < 4%

- **Significant influence on radiation budget due to absorption, emission and reflection of IR radiation (heat) and during radiative cooling processes at night, as a function of cloud cover**





HUMIDITY: STATE OF AGGREGATION OF WATER

There are three states of aggregation of water,

Phase transitions are associated with energy transfers:

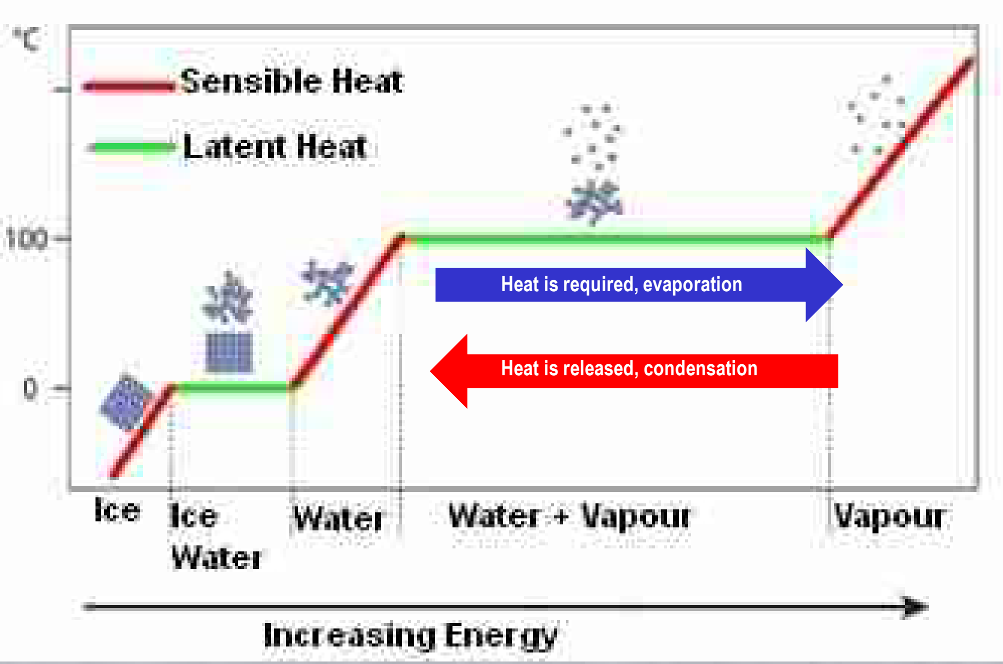
- gaseous — water vapor — (invisible gas)
- liquid — water — (cloud droplets / raindrops)
- solid — Ice — (snow, hail, graupel)

HUMIDITY: SENSIBLE AND LATENT HEAT

Energy transfer during phase transition refer to…

- **Sensible heat:** warmer / colder
- **Latent heat:** Energy (heat) is required during > melting / evaporation

  Energy (heat) is released during > freezing / condensation



these energy transfers play an important role in the development of
- Showers, Thunderstorms, Tornado
- Cyclones (Hurricane, Sirocco),
- Frost protection in fruit farming

Units of humidity measurement

Vapor pressure — partial pressure of water vapor / hPa

Specific humidity — g water vapor / kg moist air

Absolute humidity — g water vapor / m^3 dry air

Relative humidity — Actual vapor pressure / saturation vapor pressure

$0\ \% < \text{rel.humidity} < 100\ \%$

UNITS OF HUMIDITY MEASUREMENT

Dewpoint temperature Td

Temperature, at which the ambient air condenses.
When condensation takes place, Td = Tl

Spread

Tl - Td Spread

Spread = 0 : relative humidity = 100 %

Rule of thumb: Relative humidity / % = 100 - spread * 5

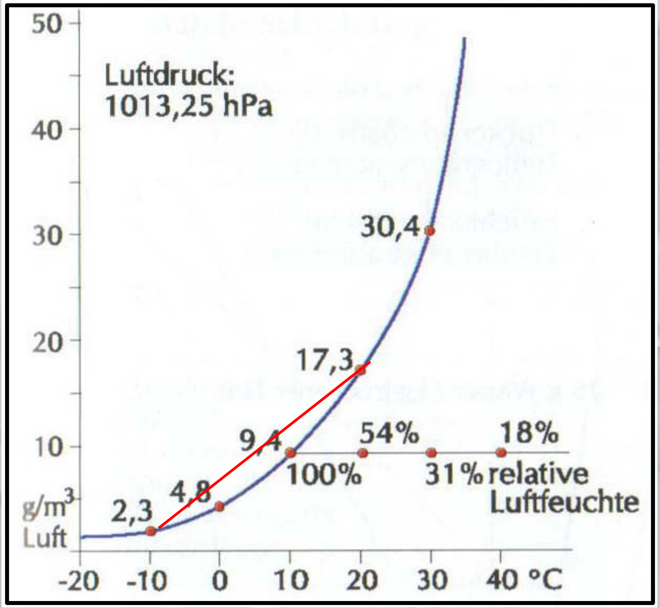
example: Tl = 20°C, Td = 17°C, spread = 3 K
relative humidity = 100 - 3*5 = 85 %

HUMIDITY: ABSOLUTE HUMIDITY

The maximum amount of water vapor in the air is a function of the temperature (vapor pressure curve, exponential !)

The higher the temperature, the higher the possible amount of water in the air

For equal amount of water in the atmosphere per volume (g/m^3), the relative humidity is lower, if the temperature is higher. (problem of humidity in living rooms in winter)



Water vapor curve

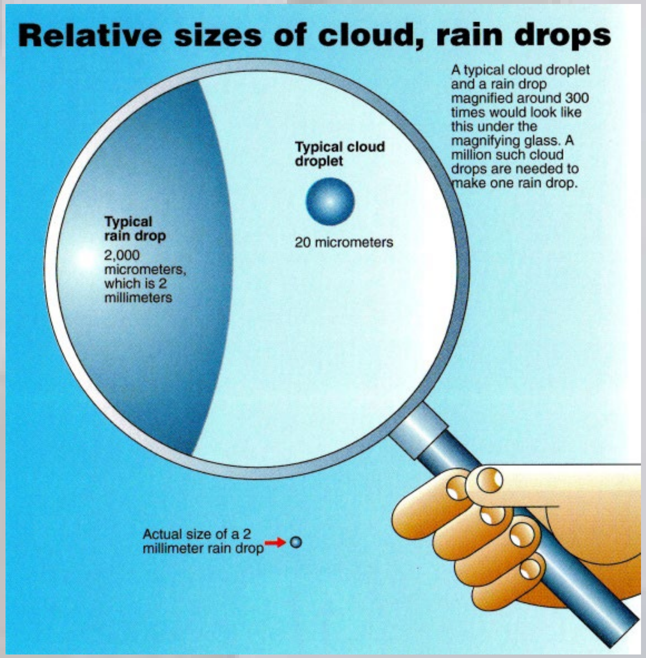
Water Vapour grams/m**3

Temperatur	30,4	17,2	9,4	4,9
30°C	100%	55%	29%	14%
20°C	●	100%	52%	26%
10°C	●	●	100%	50%
0°C	●	●	●	100%

Basic parameters: Visibility

Definition of visibility:

Visibility is the distance, at which the contrast of a white and a black target has been reduced to 5 % due to scattering and attenuation.



Reduced visibility in the armosphere …

… due to precipitation:

The higher the rainfall rate, the lower the visibility

The smaller the droplets, the lower the visibility

… due to aerosols:

The higher the rel. humidity, the higher the attenuation
the lower the visibility
(due to swelling of aerosols)

Basic parameters: Visibility

VV	Sichtweiten von	bis kleiner als	Regen	Schnee	Sprühregen	Nebel / Dunst	Schneetreiben, Staub- oder Sandsturm
90	0 m	50 m	sehr stark	sehr stark	stark	sehr dicht	sehr stark
91	50 m	200 m					stark
92	200 m	500 m		stark		mäßig dicht	mäßig
93	500 m	1 km				leicht	leicht
94	1/2 sm (1 km)	1 sm (2 km)	stark	mäßig		starker oder schwacher Dunst	(leicht)
95	1 sm (2 km)	2 sm (4 km)			mäßig		
96	2 sm (4 km)	5-6 sm (10 km)	mäßig	leicht	leicht		
97	5-6 sm (10 km)	11 sm (20 km)	leicht	sehr leicht	sehr leicht	gute Sicht	
98	11 sm (20 km)	27 sm (50 km)	sehr leicht			sehr gute Sicht	
99	ab 30 sm (50 km)					außergew. gute Sicht	

Basic parameters: Visibility

Table 7-4. Drizzle and snow intensity criteria (from USA *Fed. Meteor. Handbook No. 1*, Sep 2005), and their weather-map symbols and Meteorological Aviation Report (METAR) codes for continuous precipitation.

Precip. Intensity	Visibility (x_v)		Symbol on Map / METAR Code	
	miles	≈km	Drizzle	Snow
heavy	$x_v \leq 0.25$	$x_v \leq 0.4$	, , , , +DZ	* * * * +SN
moderate	$0.25 < x_v \leq 0.5$	$0.4 < x_v \leq 0.8$	, , , DZ	* * * SN
light	$x_v > 0.5$	$x_v > 0.8$	, , –DZ	* * –SN

CHECKLIST GLOBAL CIRCULATION

Basic Parameters

- ✓ The Tropopause limits the Troposphere, its Height varies from 6 km (Polar) to 18 km (Tropics)
- ✓ Weather phenomena develop in the Troposphere due to available water vapour
- ✓ Water vapour is the most important greenhouse gas (absorption)
- ✓ The Temperature decreases with 1 K/100m (dry) or 0.65 K/100m (moist)

Questions you should be able to answer

Basic Parameters

- ✓ Why is the temperature decreasing with height?
  - ✓ Air exerts expansion work against decreasing Pressure.
- ✓ Where is it colder in 10 km height? Over the North Pole or over the Equator?
  - ✓ Equator, because over the Pole, the Temperature remains constant after 6 km (Tropopause)
- ✓ What determines the Height of a Pressure Level, e.g. 500 hPa?
  - ✓ The average Temperature of the Layer
- ✓ What is the geostrophic Wind?
  - ✓ Balance of Pressure Gradient and Coriolis Force
- ✓ What changes the wind as well?
  - ✓ Curvature of Isobars: Higher windspeed in anticyclonic curvature,
  - ✓ Coriolis and Pressure gradient act in the same direction
- ✓ How is the visibility defined?
  - ✓ When the contrast between a white and black target goes below 5 %