



XLVI CORSO DI AGGIORNAMENTO IN FISICA - ANNO 2024
Cambiamento climatico e transizione energetica

Imparare la fisica dalle osservazioni dell'atmosfera e del clima

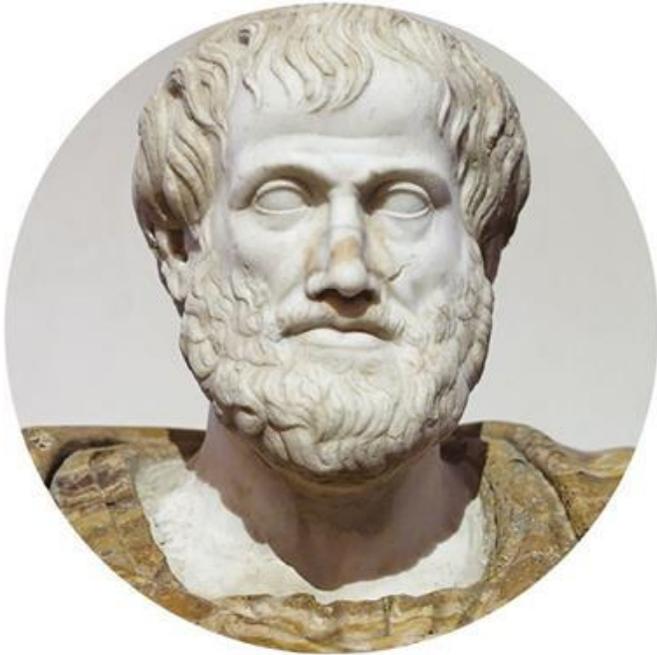


Dino Zardi
Università di Trento

ARISTOTELE FISICA

A cura di Roberto Radice

Testo greco a fronte



 BOMPIANI
IL PENSIERO OCCIDENTALE

Φυσικά

PHYSICAL SCIENCE
STUDY
COMMITTEE (P.S.S.C)
S. Jerslin

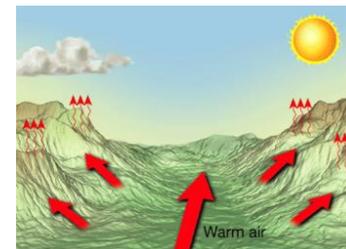
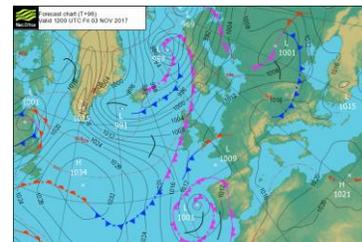
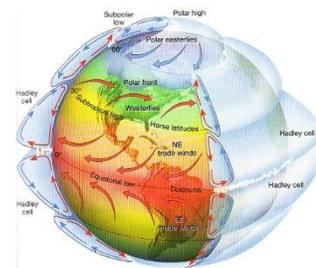


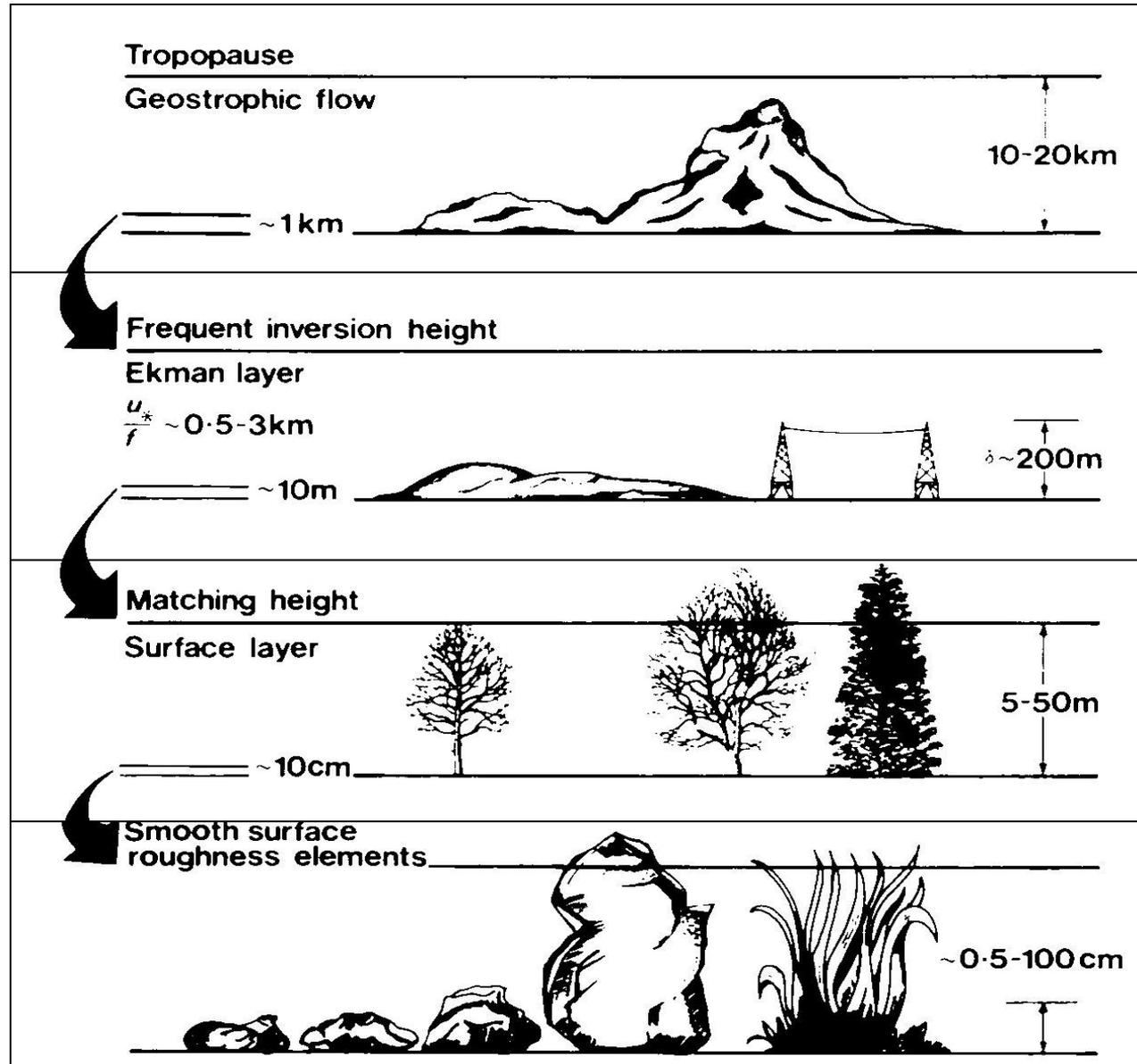


Scale

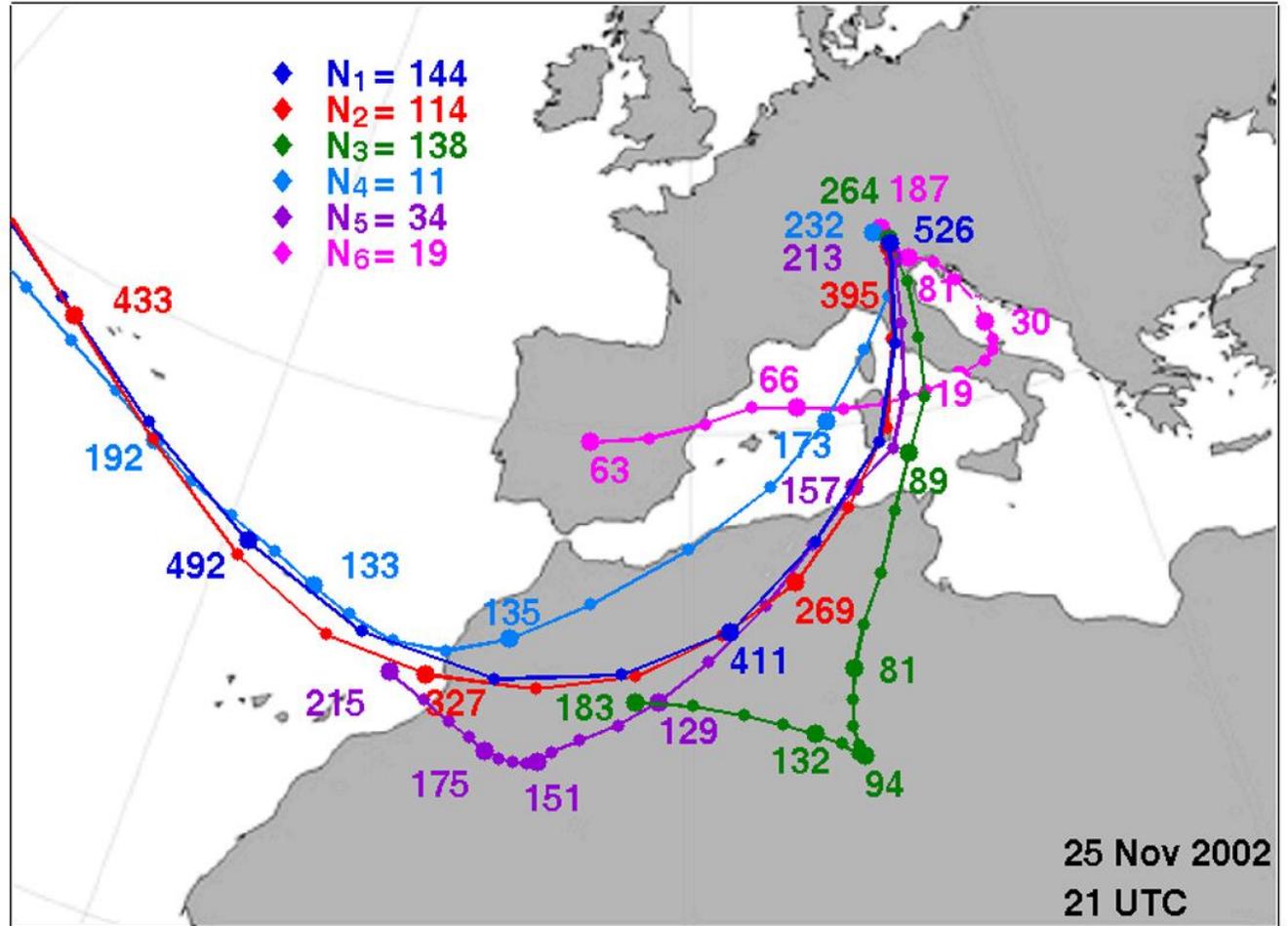
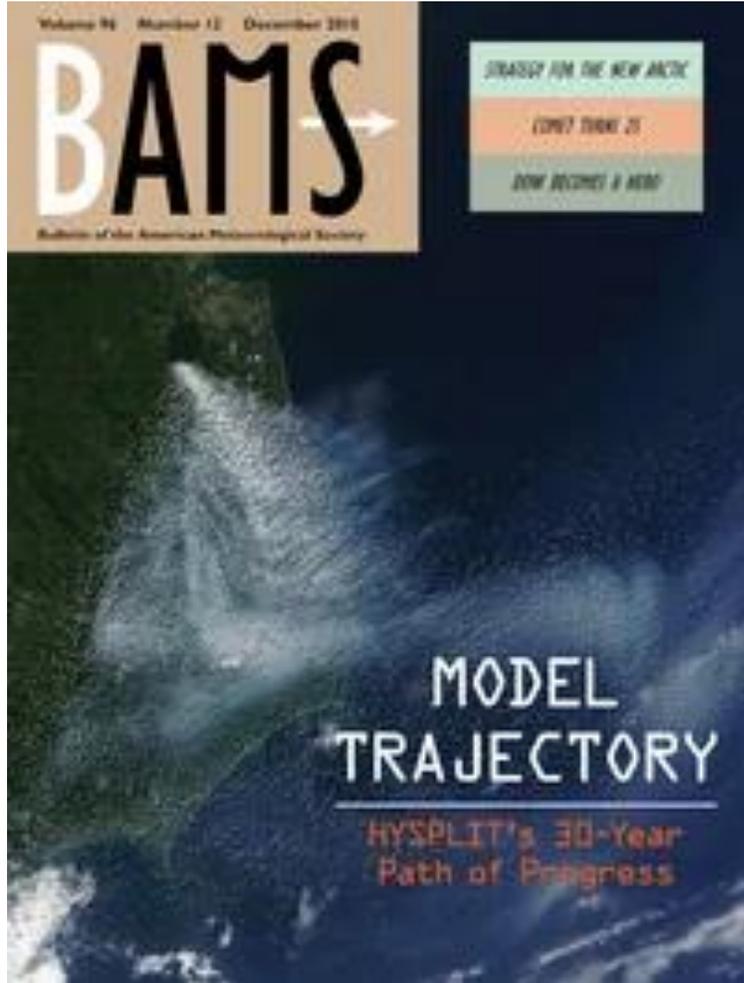
Scale spaziali e temporali dei processi dell'atmosfera e dell'oceano

		Scale spaziali orizzontali			
		10000 km	1000 km	100 km	10 km
Scale temporali	1 anno	Scala planetaria			
	1 settimana		Scala sinottica		
	1 giorno			Mesoscala	
	1 ora				Microscale





Meccanica del punto materiale

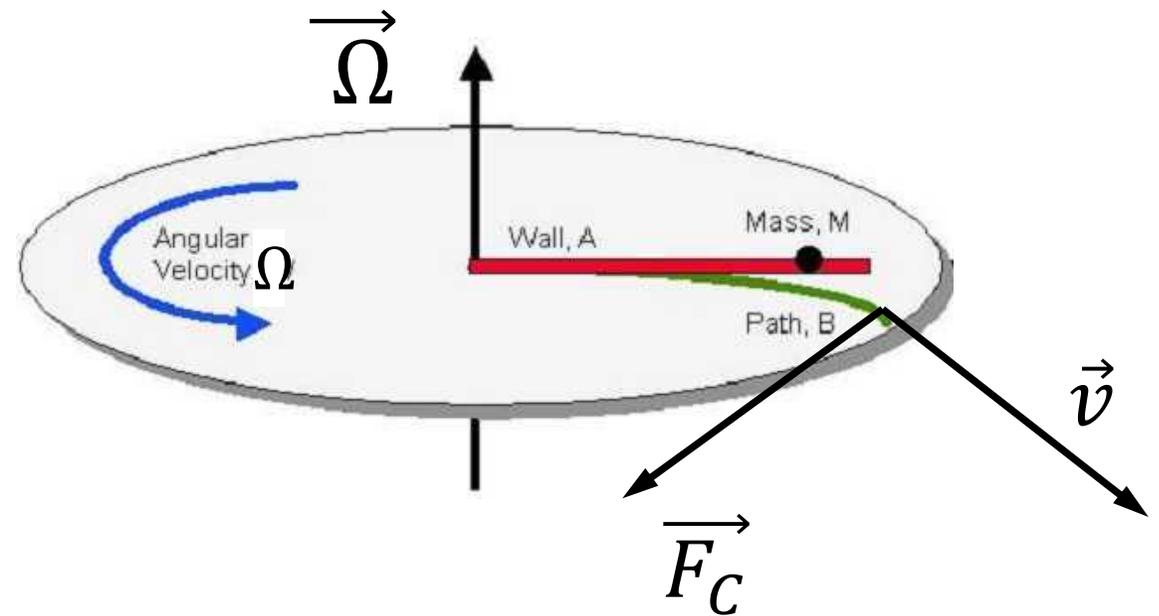


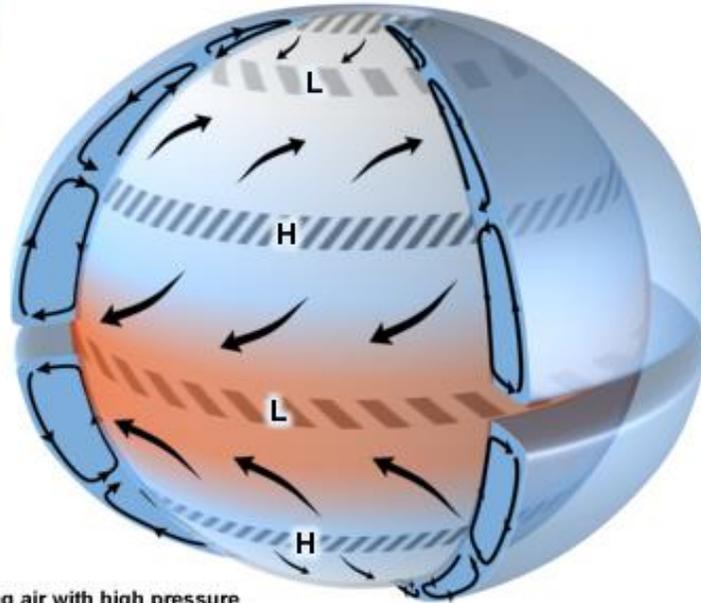
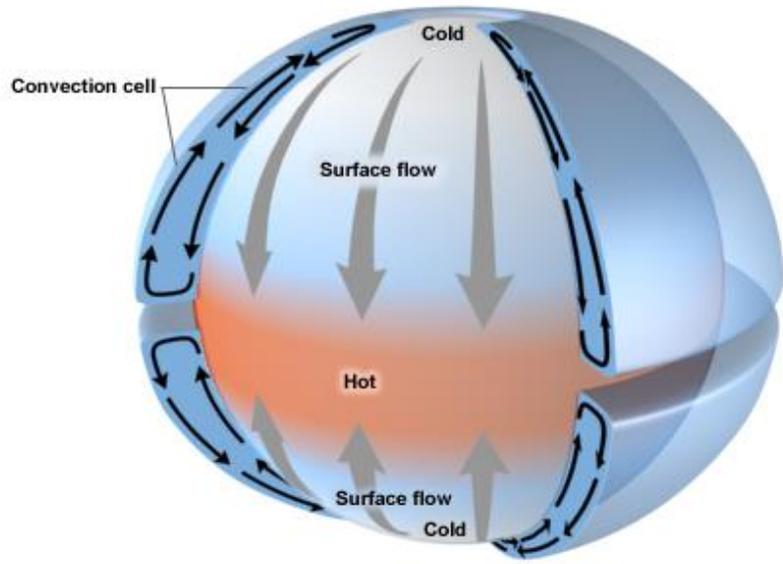
Effetti non inerziali



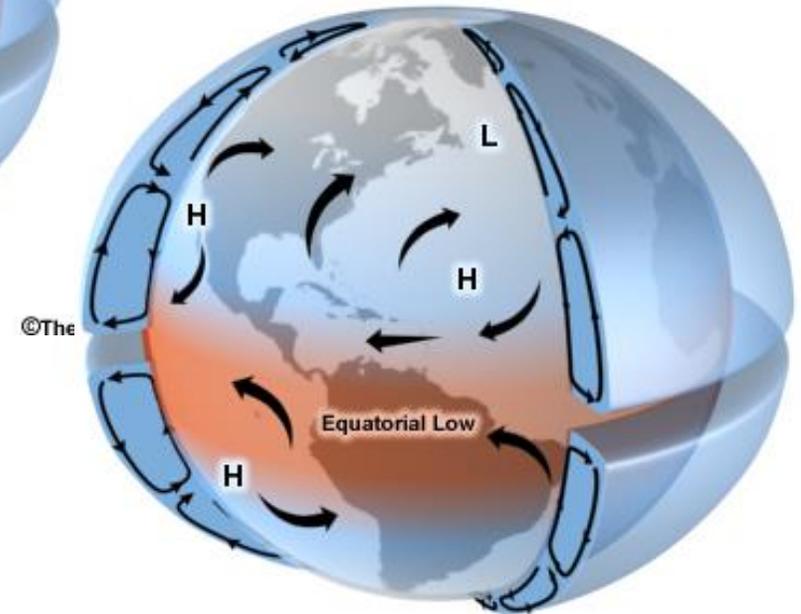
Gaspard-Gustave de Coriolis
(1792 – 1843)

$$\vec{F}_C = -2m \vec{\Omega} \times \vec{v}$$





 Sinking air with high pressure
 Rising air with low pressure



Equilibrio geostrofico

$$\vec{v}_G = \hat{k} \times \frac{1}{\rho f} \nabla p$$

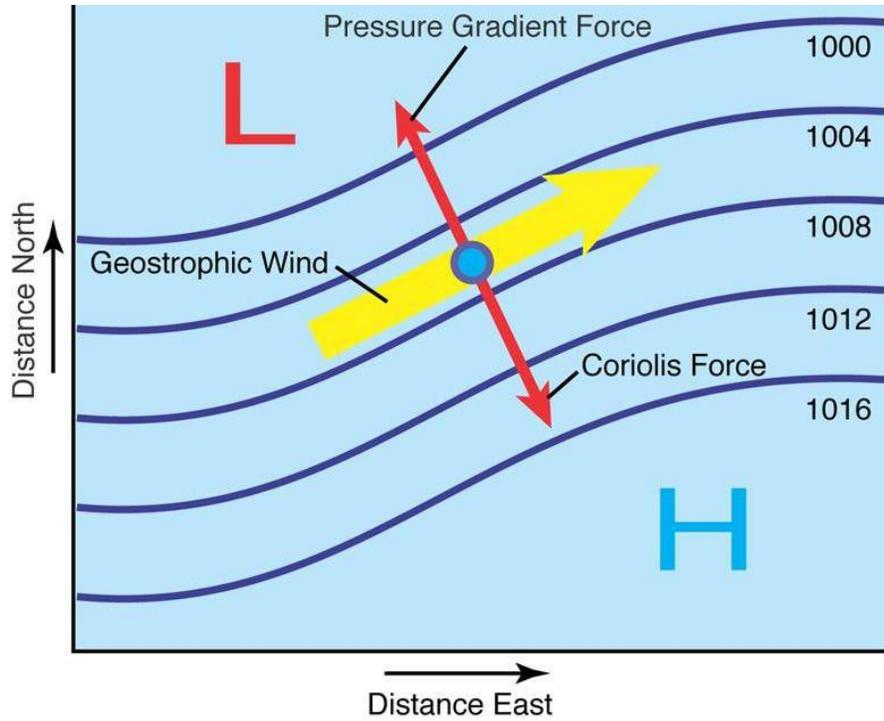
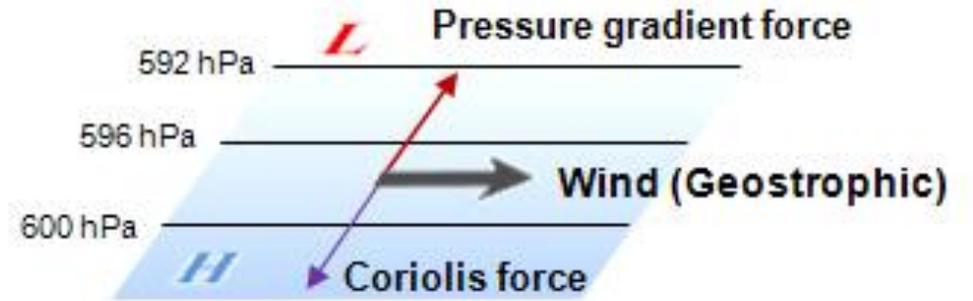
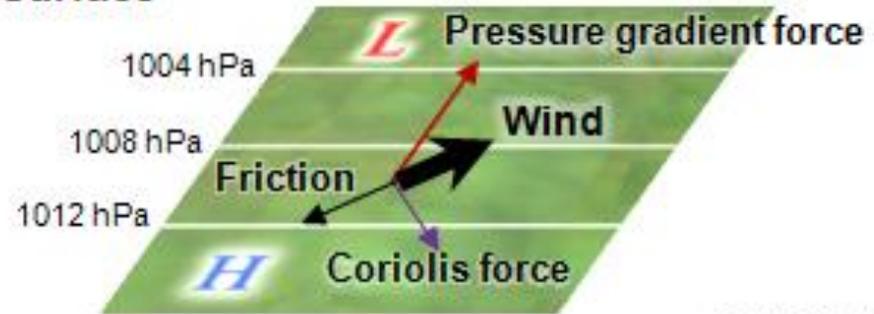


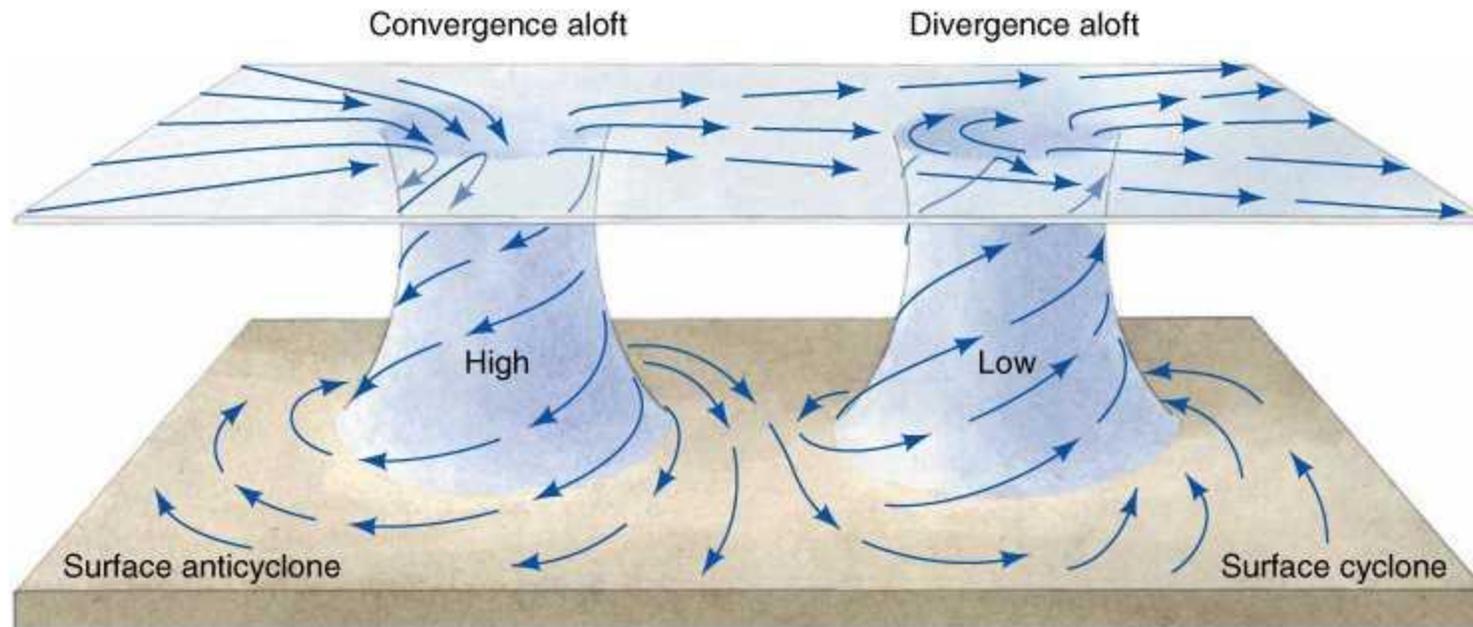
FIG 04-09
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Aviation Weather

Free Atmosphere (no friction)

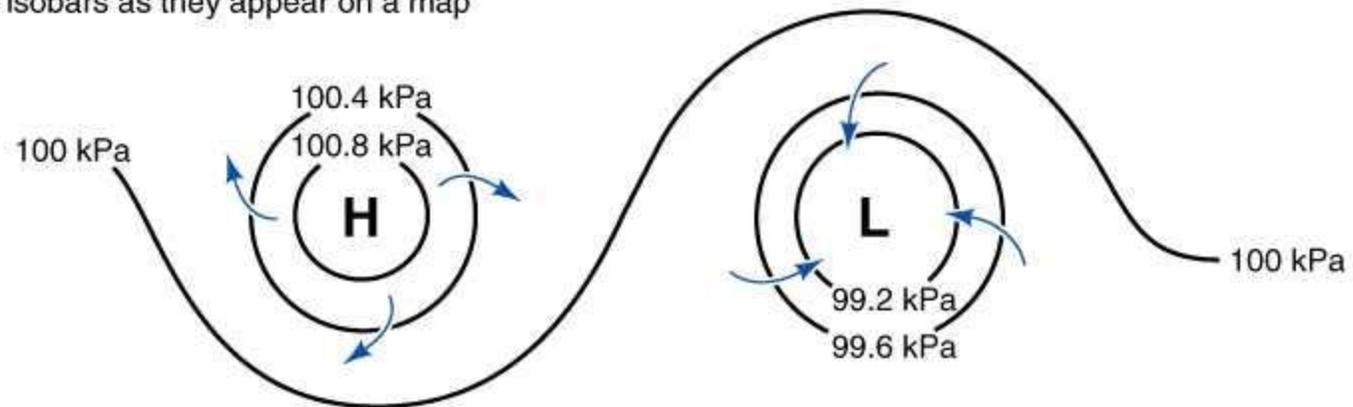


Surface





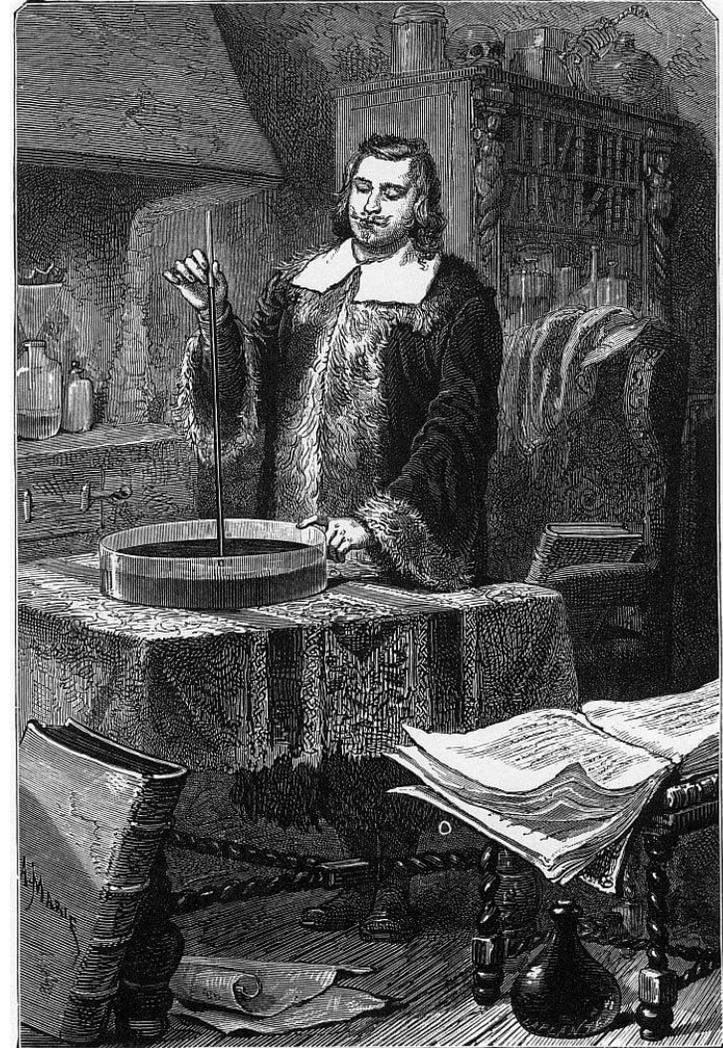
Surface isobars as they appear on a map



Meccanica del continuo

«Noi viviamo sommersi nel fondo d'un pelago d'aria elementare, la quale per esperienze indubitate si sa che pesa, e tanto, che questa grossissima vicino alla superficie terrena, pesa circa la quattrocentesima parte del peso dell'acqua»

Lettera a Michelangelo Ricci, 11 giugno 1644



Evangelista Torricelli
(Roma 1608 - Firenze 1647)

https://it.wikipedia.org/wiki/Evangelista_Torricelli

Equazione di stato dei gasi ideali

$$p = \rho R T$$

$$R = R^*/M$$

Equilibrio idrostatico

$$\frac{dp}{dz} = -\rho g$$

$$\frac{dp}{dz} = -\frac{p}{RT} g$$

Atmosfera isoterma

$$p(z) = p_0 e^{-\frac{z}{H}}$$

$$H = \frac{RT}{g} = \frac{R^*T}{Mg}$$

Fenomeni elettrici



Electricity in the Atmosphere

9-1 The electric potential gradient of the atmosphere

On an ordinary day over flat desert country, or over the sea, as one goes upward from the surface of the ground the electric potential increases by about 100 volts per meter. Thus there is a vertical electric field E of 100 volts/m in the air. The sign of the field corresponds to a negative charge on the earth's surface. This means that outdoors the potential at the height of your nose is 200 volts higher than the potential at your feet! You might ask: "Why don't we just stick a pair of electrodes out in the air one meter apart and use the 100 volts to power our electric lights?" Or you might wonder: "If there is *really* a potential difference of 200 volts between my nose and my feet, why is it I don't get a shock when I go out into the street?"

We will answer the second question first. Your body is a relatively good conductor. If you are in contact with the ground, you and the ground will tend to make one equipotential surface. Ordinarily, the equipotentials are parallel to the surface, as shown in Fig. 9-1(a), but when you are there, the equipotentials are distorted, and the field looks somewhat as shown in Fig. 9-1(b). So you still have very nearly zero potential difference between your head and your feet. There are charges that come from the earth to your head, changing the field. Some of them may be discharged by ions collected from the air, but the current of these is very small because air is a poor conductor.

9-1 The electric potential gradient of the atmosphere

9-2 Electric currents in the atmosphere

9-3 Origin of the atmospheric currents

9-4 Thunderstorms

9-5 The mechanism of charge separation

9-6 Lightning

Reference: Chalmers, J. Alan, *Atmospheric Electricity*, Pergamon Press, London (1957).

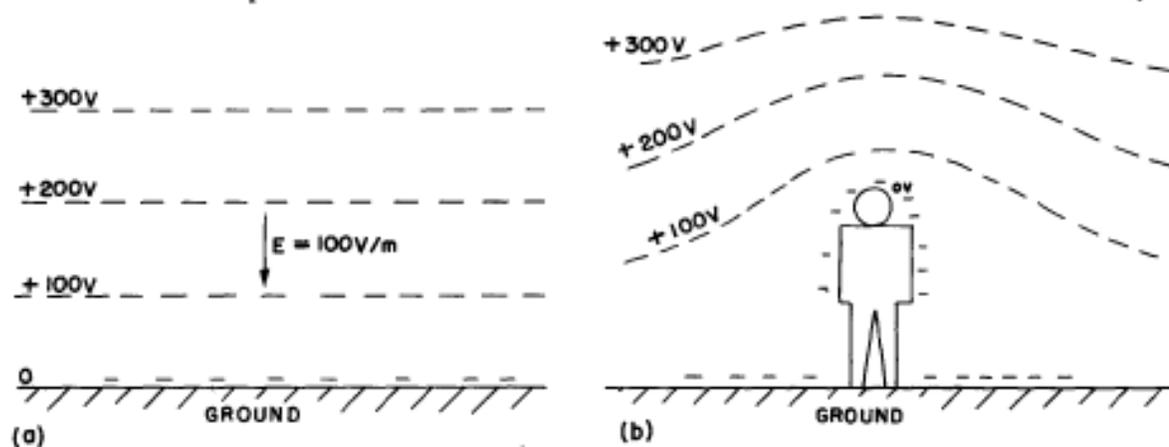


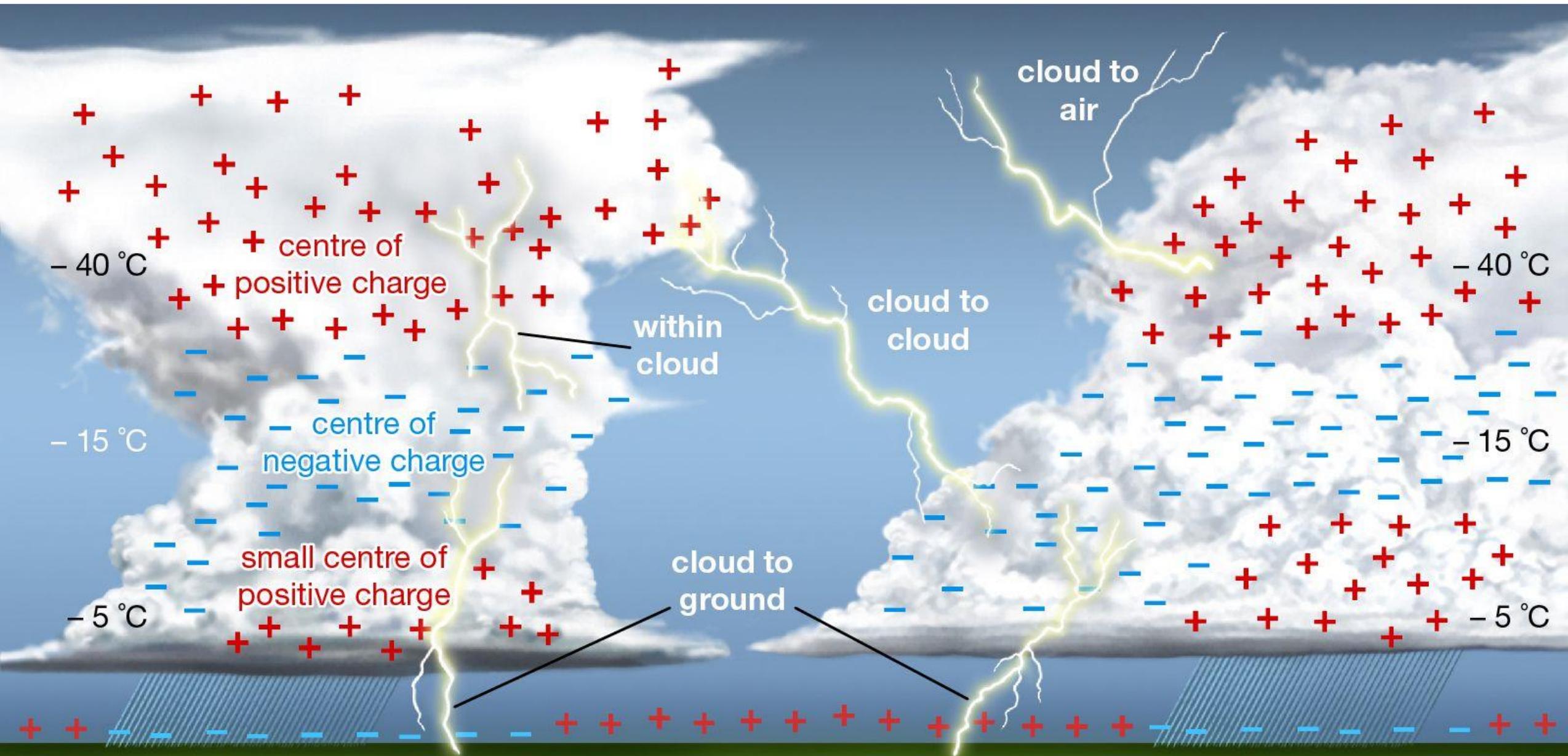
Fig. 9-1. (a) The potential distribution above the earth. (b) The potential distribution near a man in an open flat place.

VOLUME II

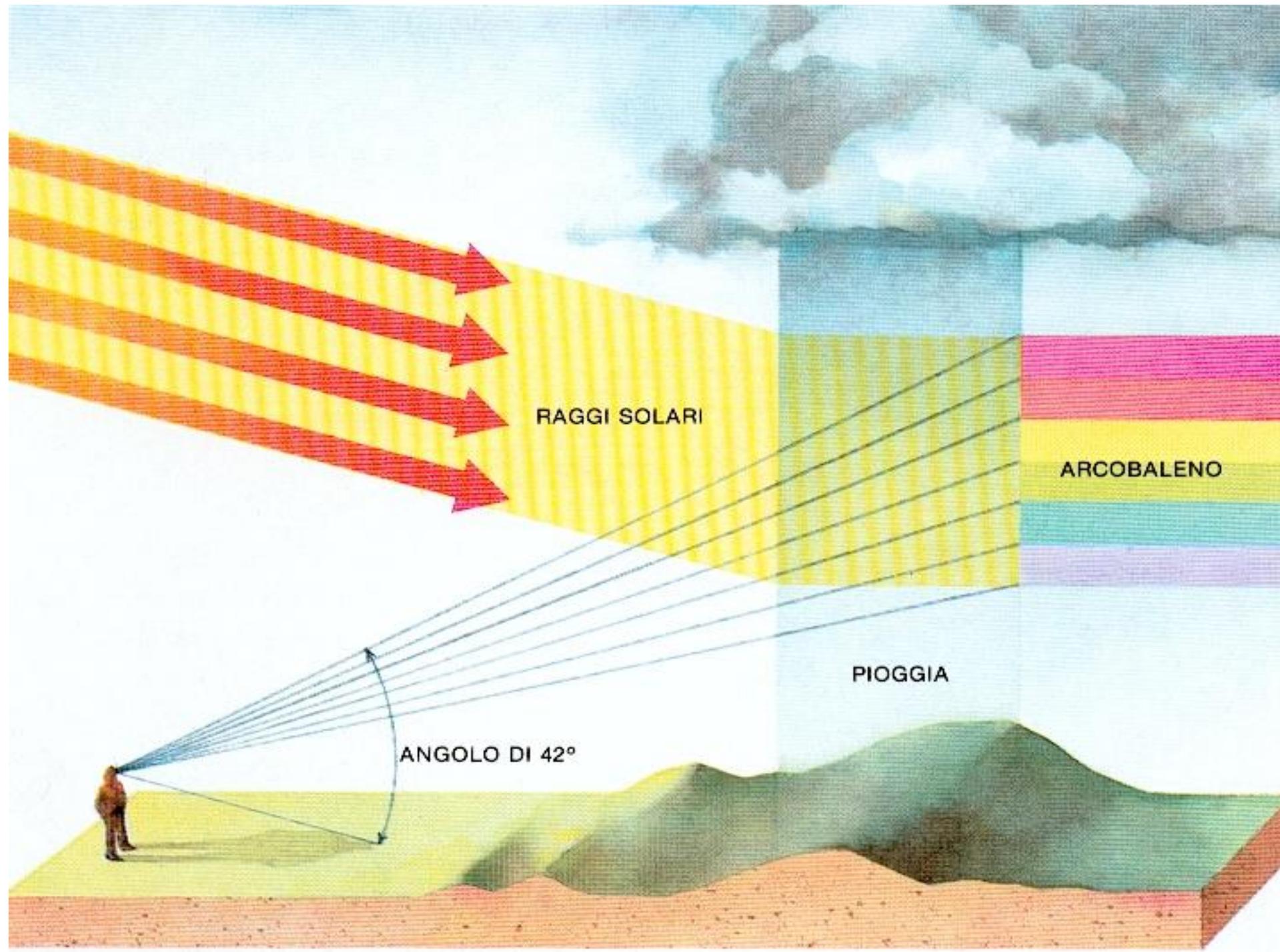
The Feynman

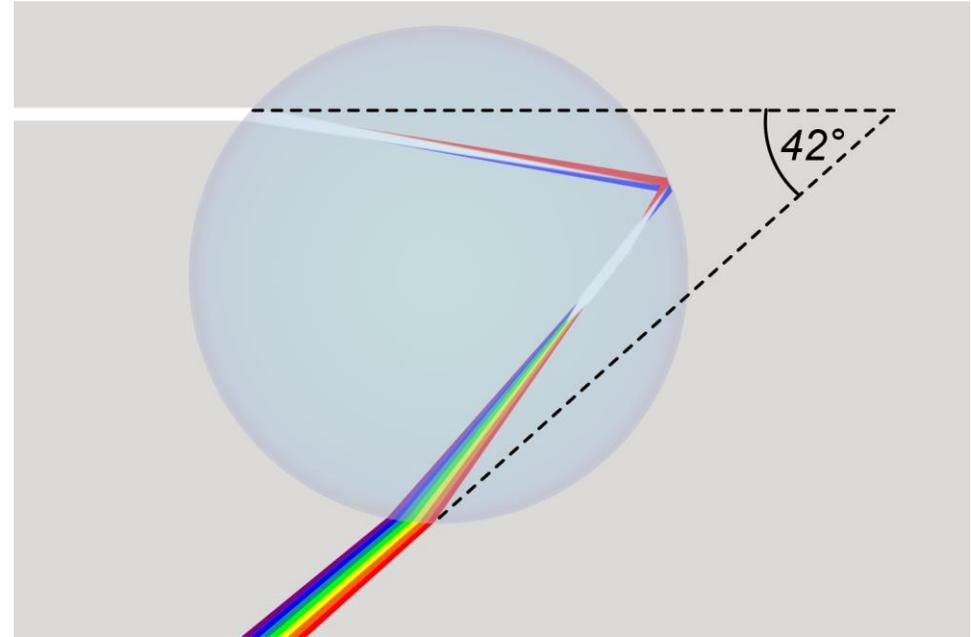
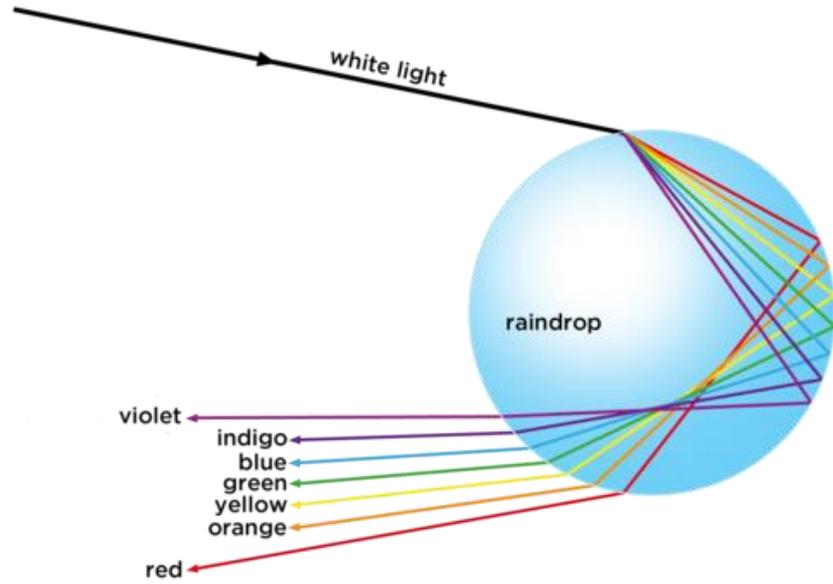
LECTURES ON
PHYSICS

FEYNMAN • LEIGHTON • SANDS

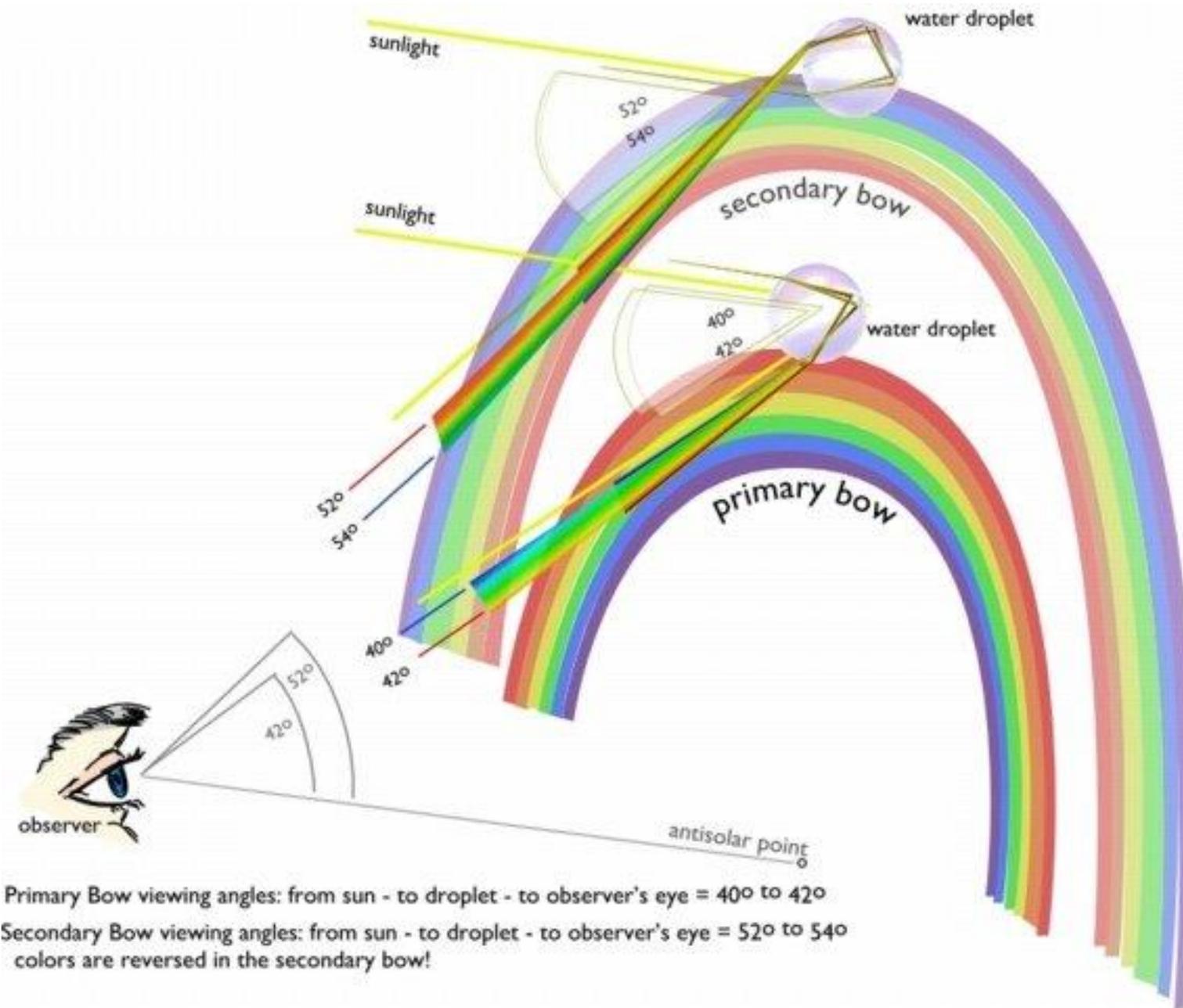


Ottica





By KES47 - Own work, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=10636870>



Primary Bow viewing angles: from sun - to droplet - to observer's eye = 40° to 42°
 Secondary Bow viewing angles: from sun - to droplet - to observer's eye = 52° to 54°
 colors are reversed in the secondary bow!

Given a spherical raindrop, and defining the perceived angle of the rainbow as 2φ , and the angle of the internal reflection as 2β , then the angle of incidence of the Sun's rays with respect to the drop's surface normal is $2\beta - \varphi$. Since the angle of refraction is β , [Snell's law](#) gives us $\sin(2\beta - \varphi) = n \sin \beta$, where $n = 1.333$ is the refractive index of water.

Solving for φ , we get $\varphi = 2\beta - \arcsin(n \sin \beta)$.

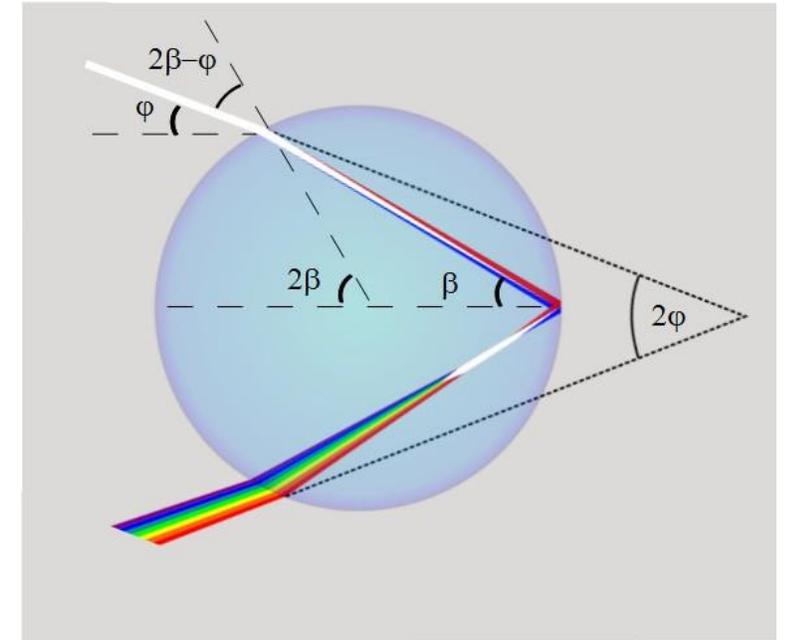
The rainbow will occur where the angle φ is maximum with respect to the angle β . Therefore, from [calculus](#), we can set $d\varphi/d\beta = 0$, and solve for β , which yields

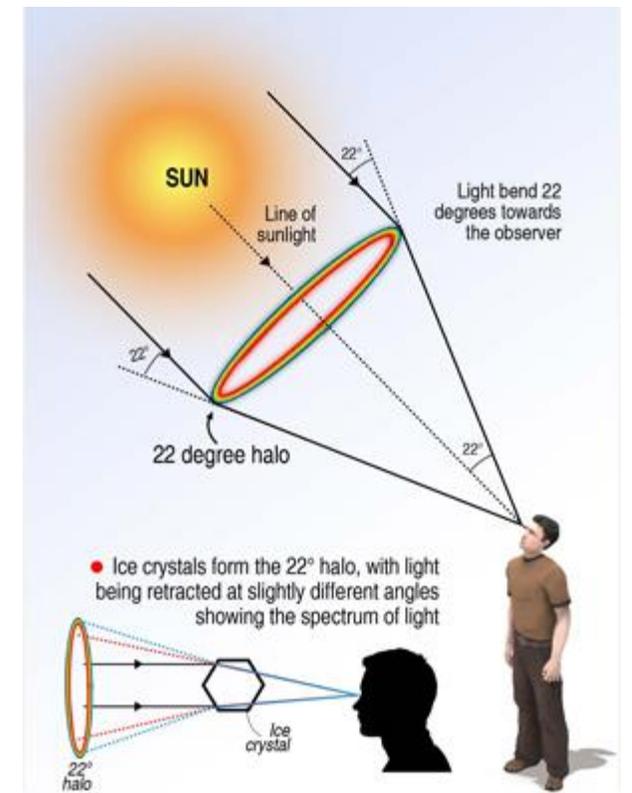
$$\beta_{max} = \arccos\left(\frac{2\sqrt{-1 + n^2}}{\sqrt{3}n}\right) \sim 40.2^\circ$$

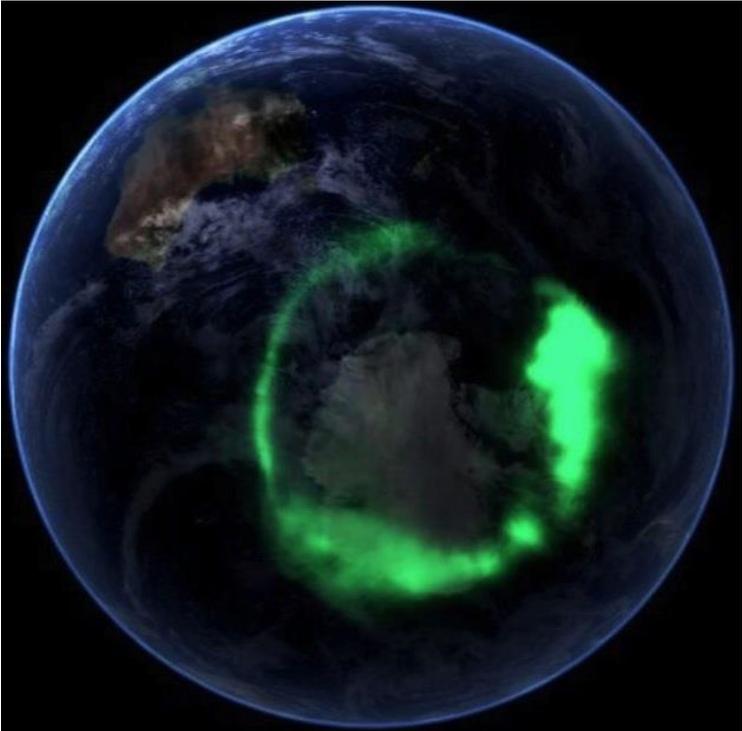
Substituting back into the equation for φ yields $2\varphi_{max} \approx 42^\circ$.

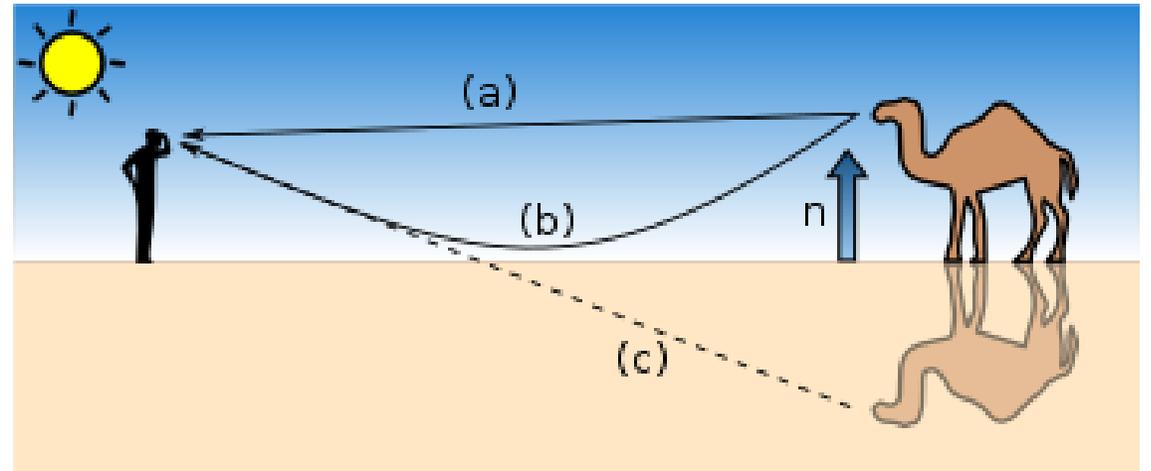
For red light (wavelength 750 nm, $n = 1.330$ based on [the dispersion relation of water](#)), the radius angle is 42.5°

For blue light (wavelength 350 nm, $n = 1.343$), the radius angle is 40.6° .

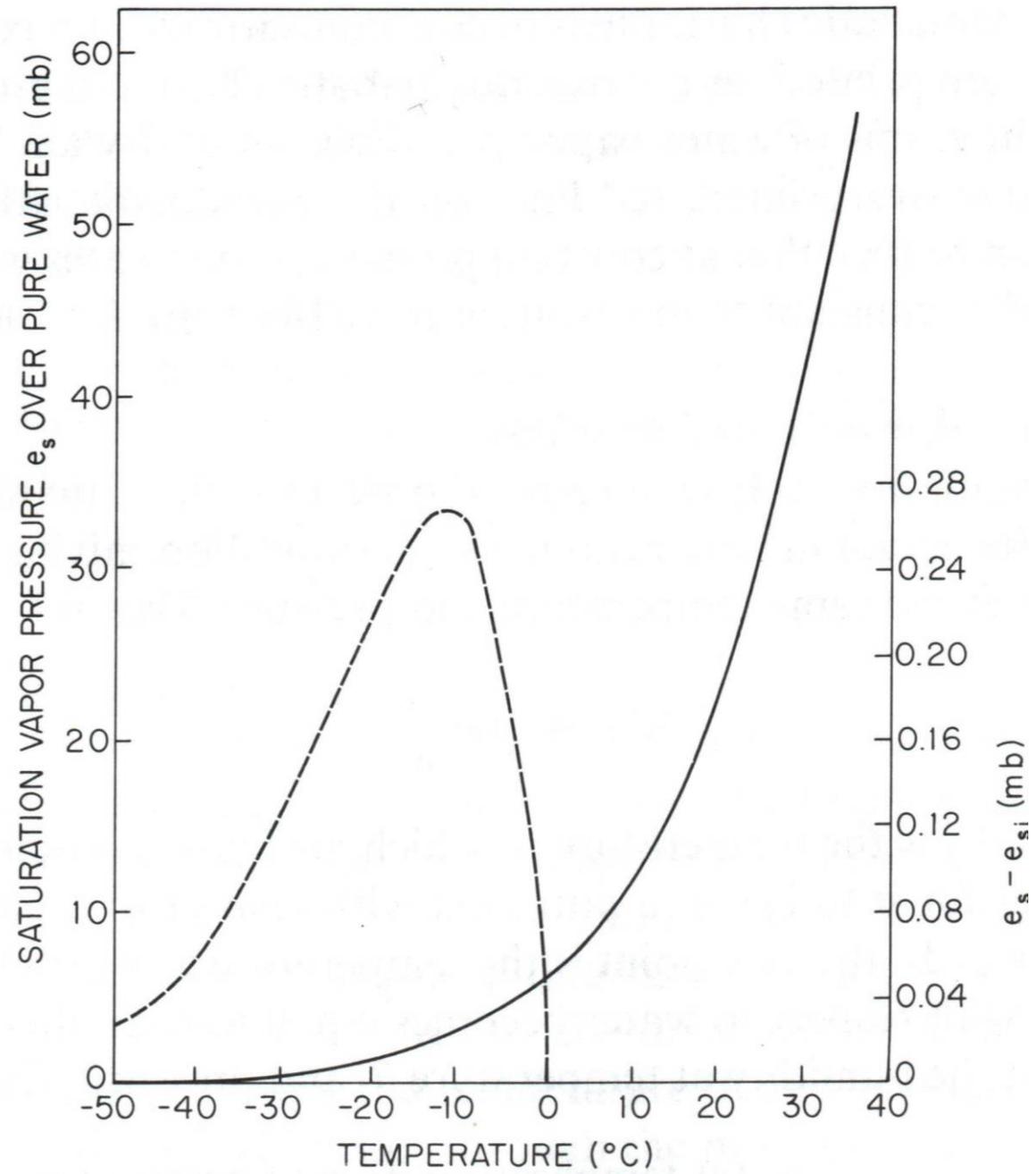


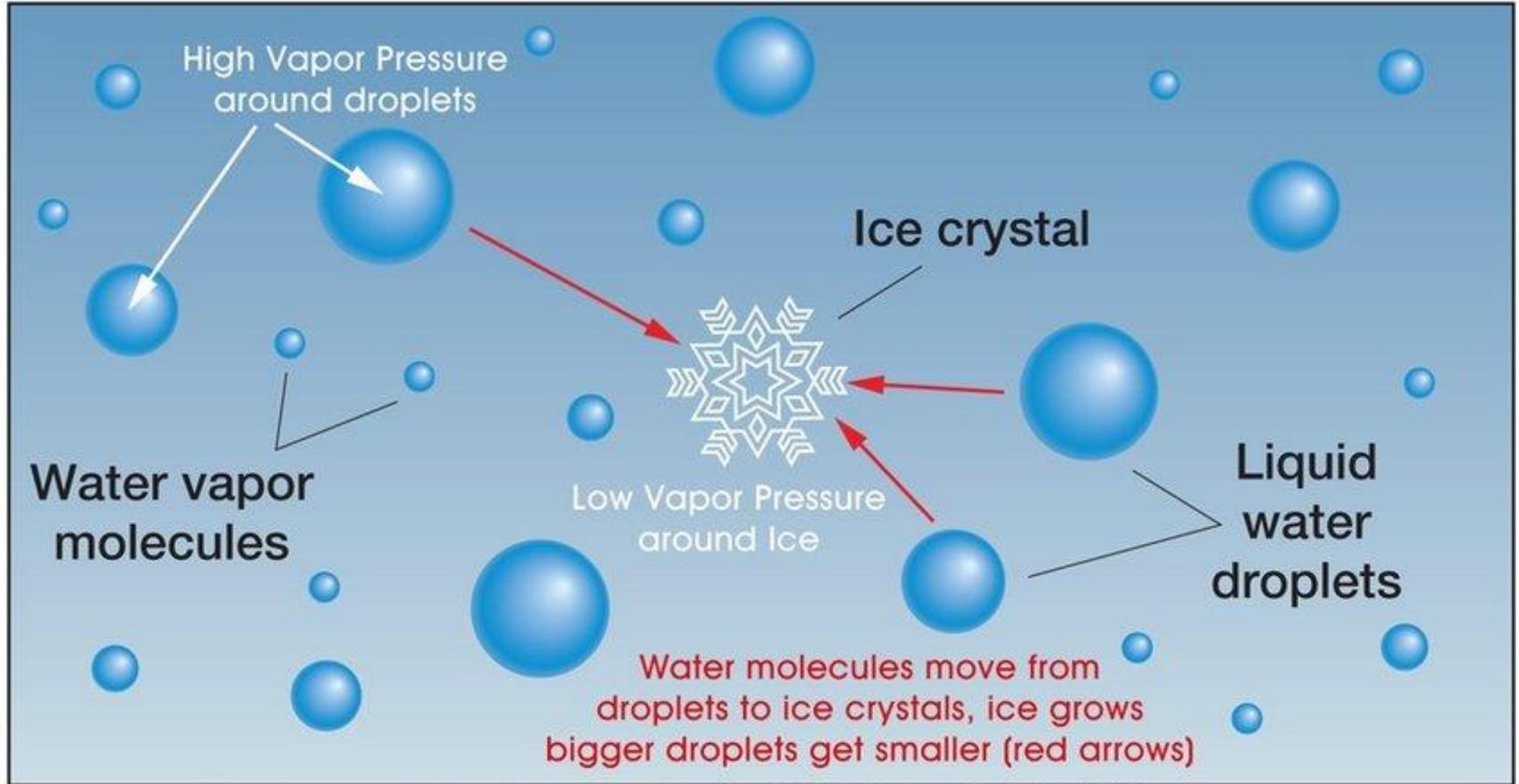






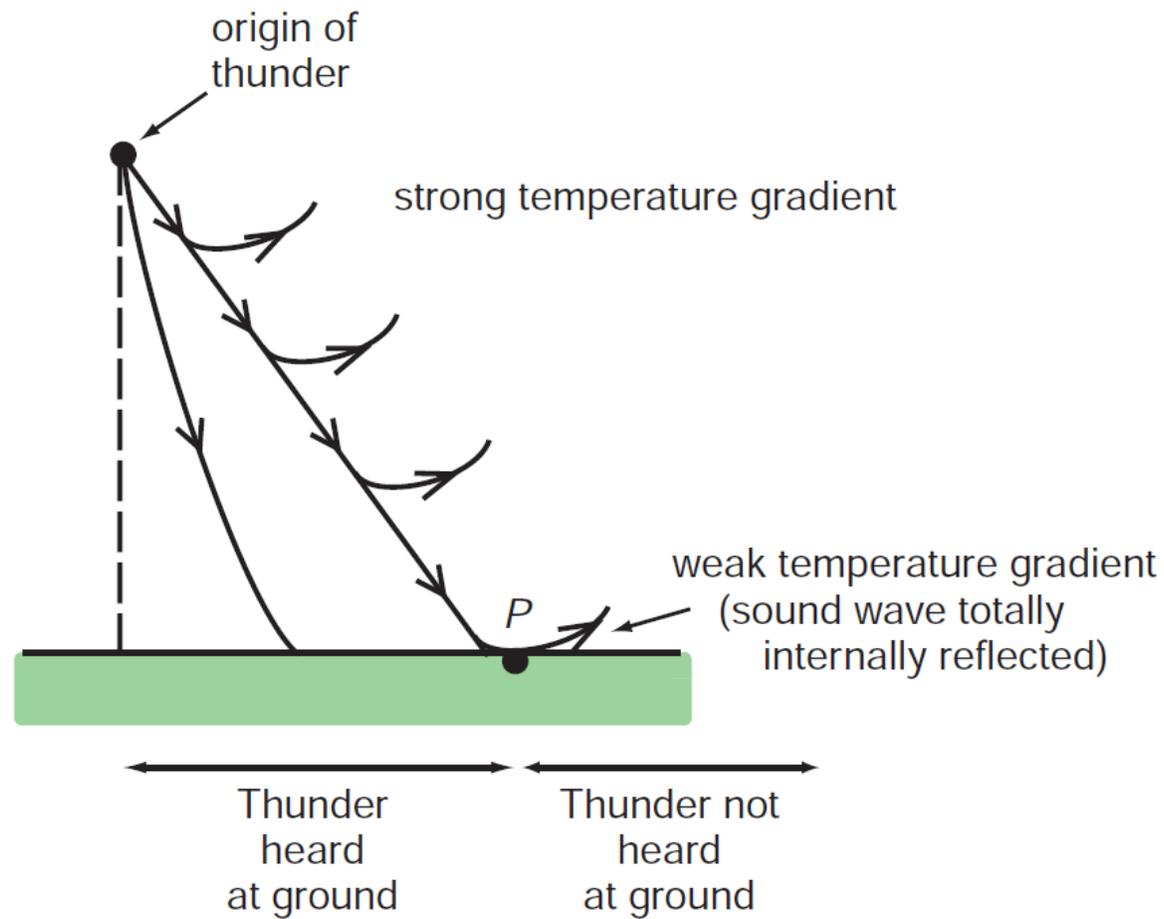
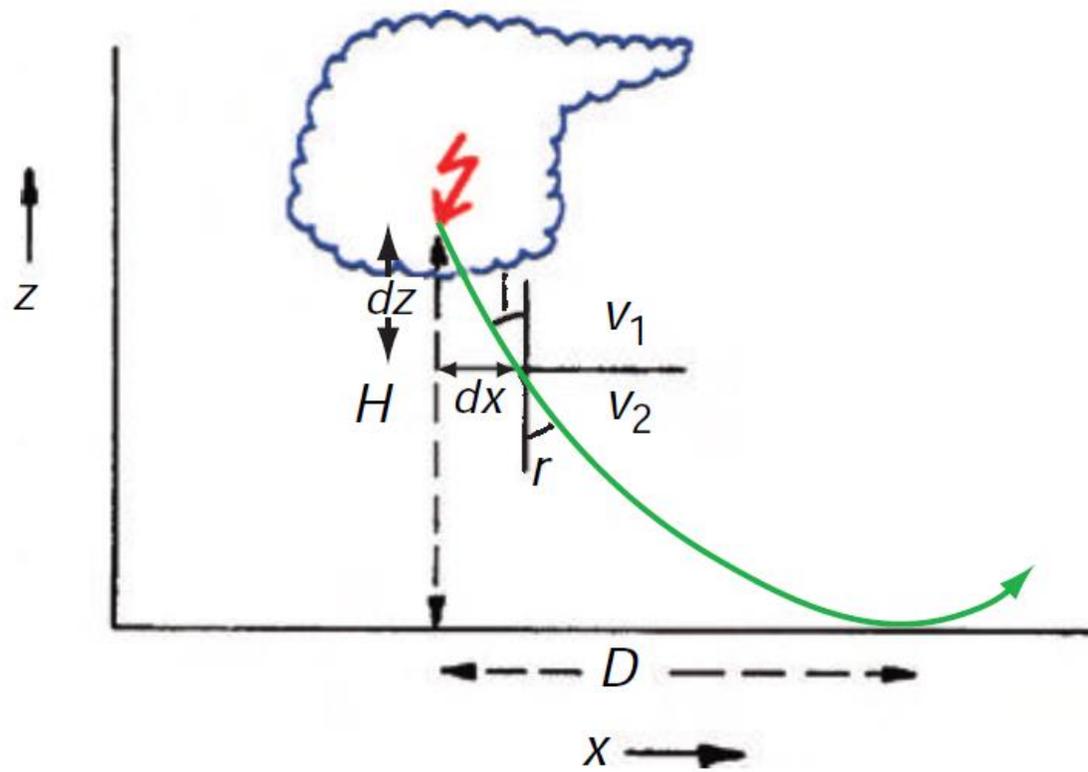
Cambiamenti di stato





Acustica





Fisica statistica

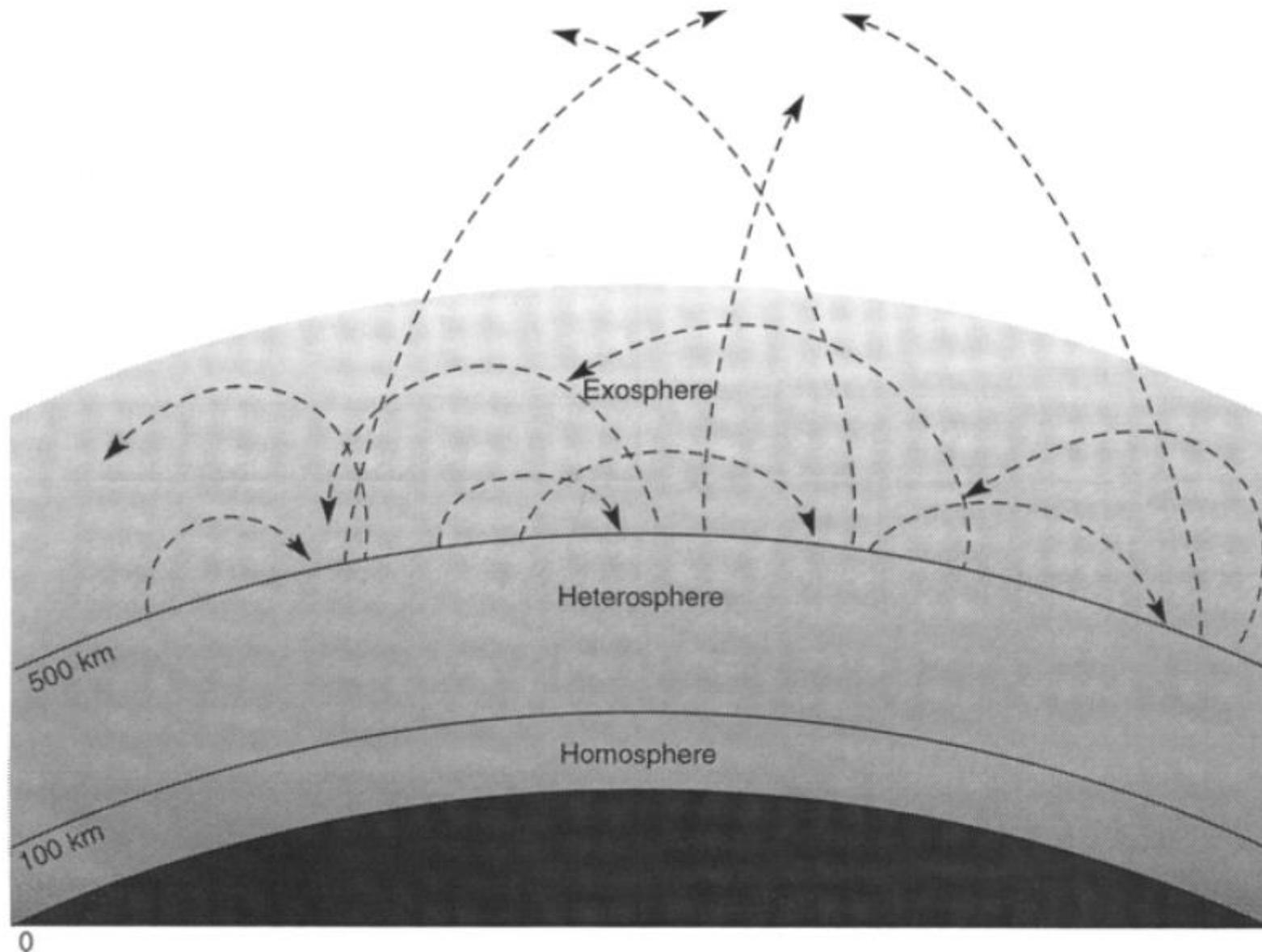
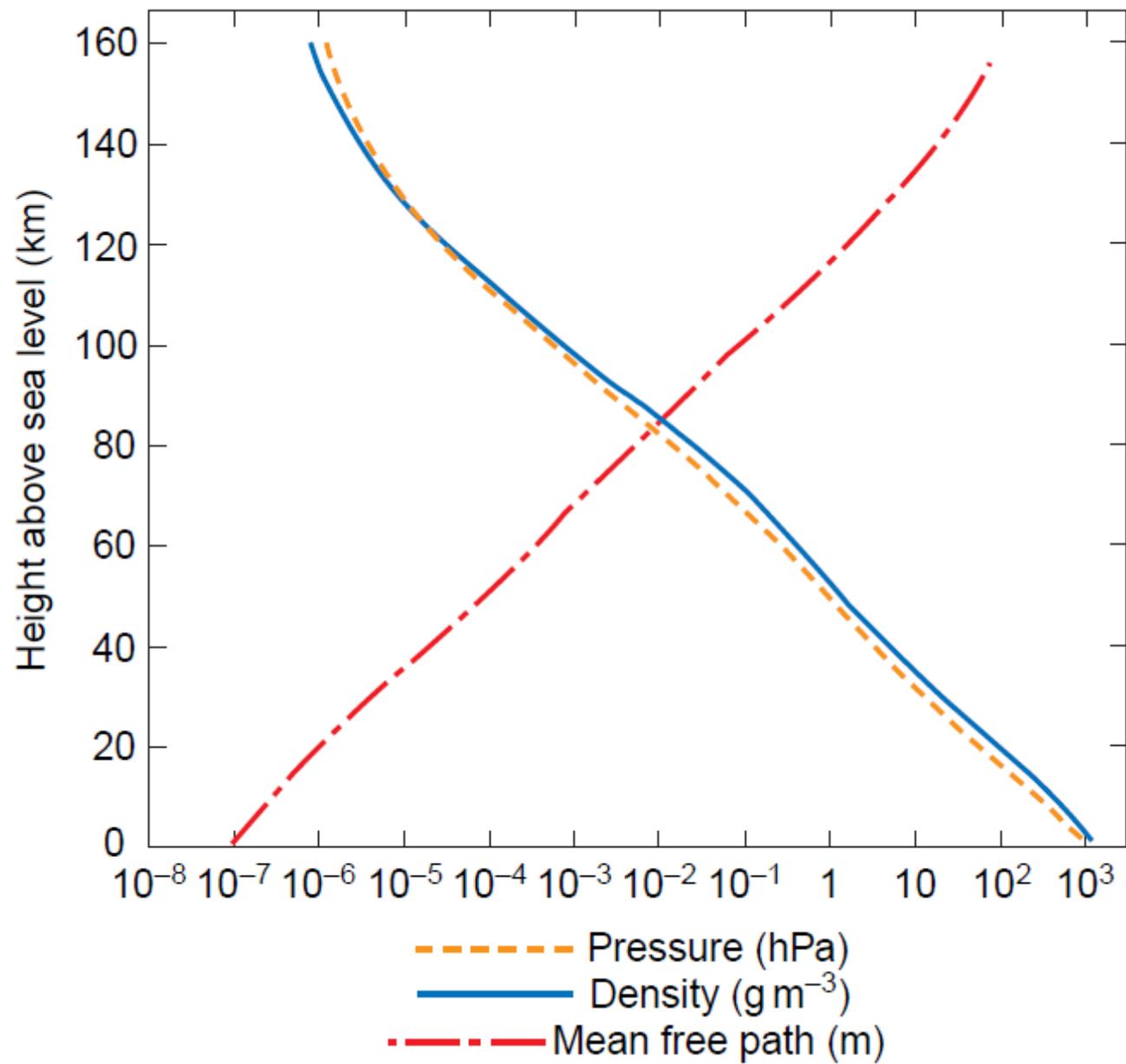


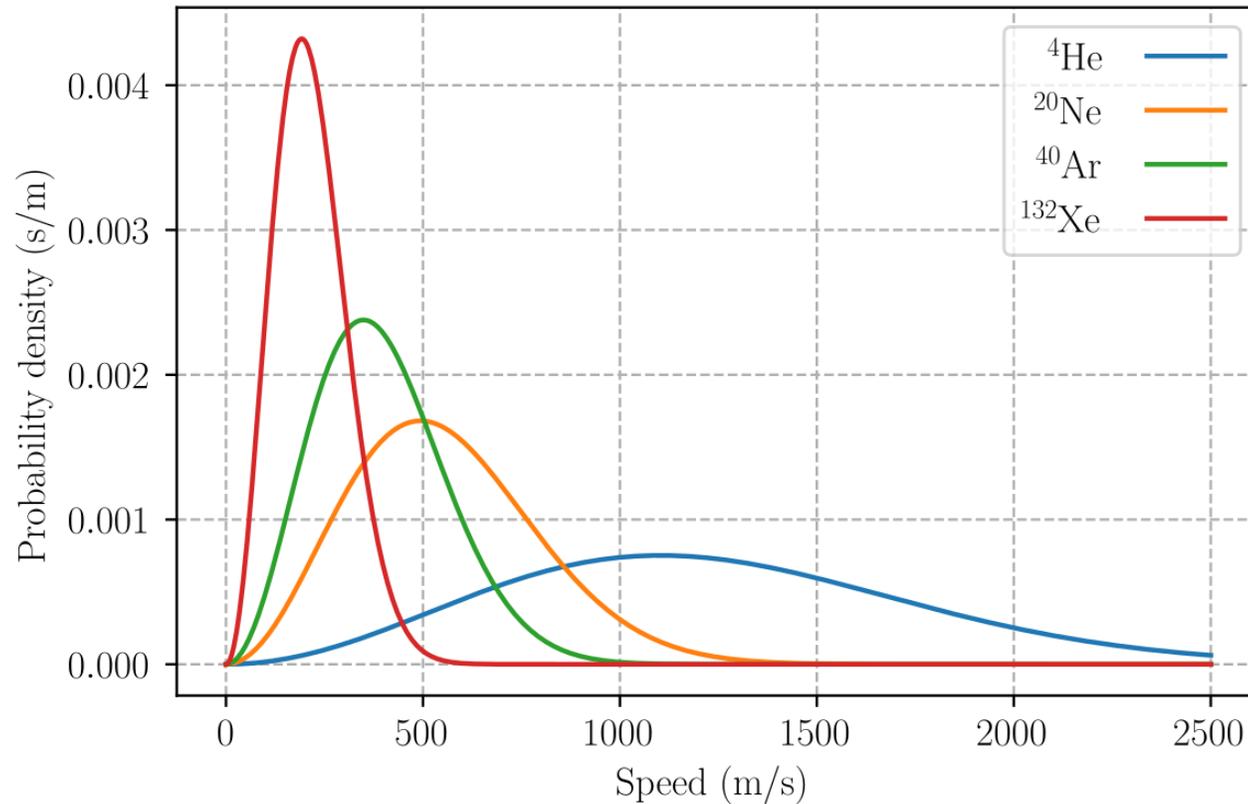
Figure 1.5 Schematic cross section of the atmosphere illustrating the homosphere, heterosphere, and the exosphere, in which molecular trajectories are shown.



Distribuzione di Maxwell-Boltzmann

$$f(v) = 4\pi \left(\frac{m}{2\pi kT} \right)^{3/2} v^2 e^{-mv^2/2kT}$$

Distribution of Speeds for Noble Gases at Room Temperature T=25°C



Velocità di fuga

$$v_e = \sqrt{2g_0 a} \sim 11 \text{ km s}^{-1}$$

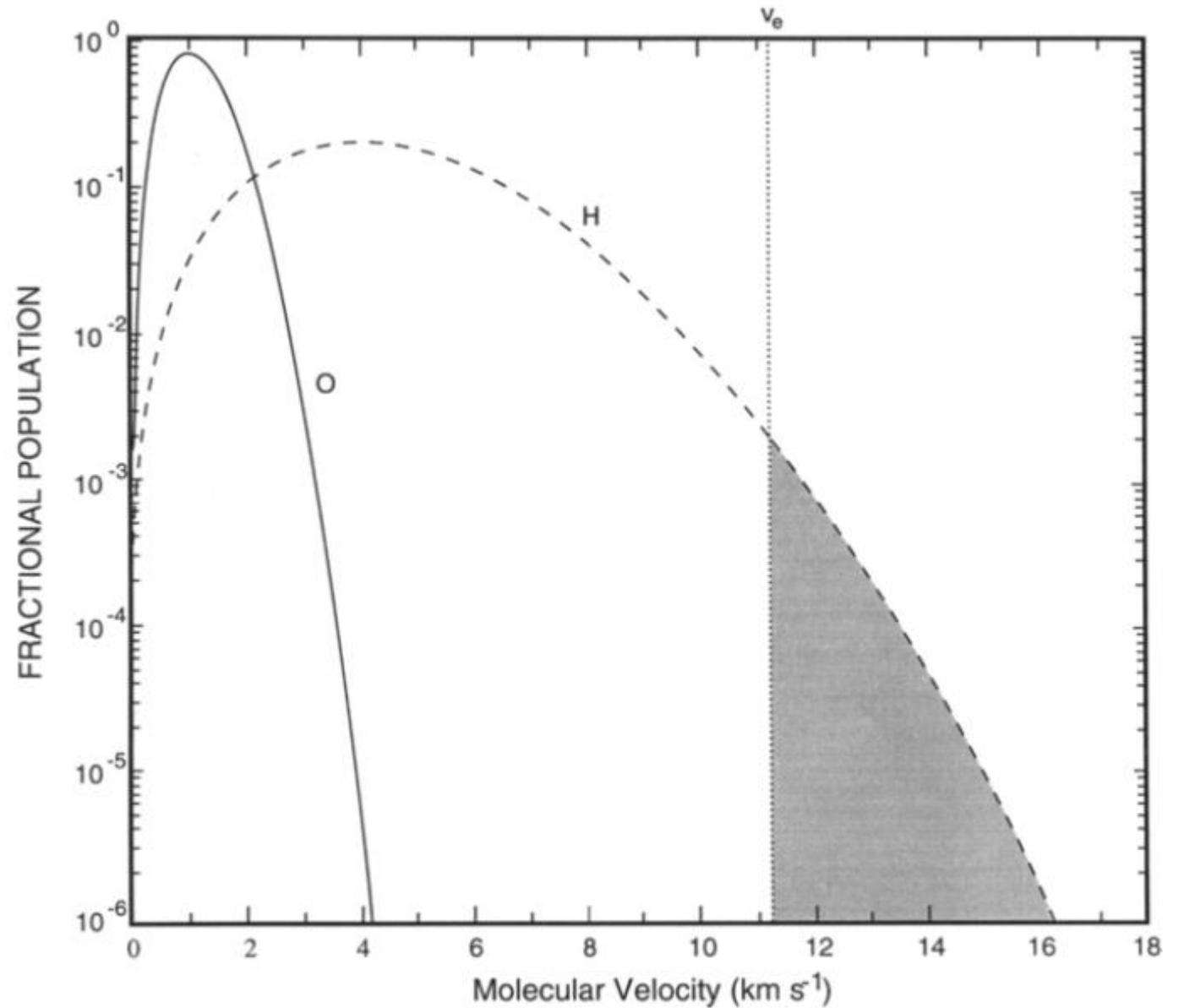
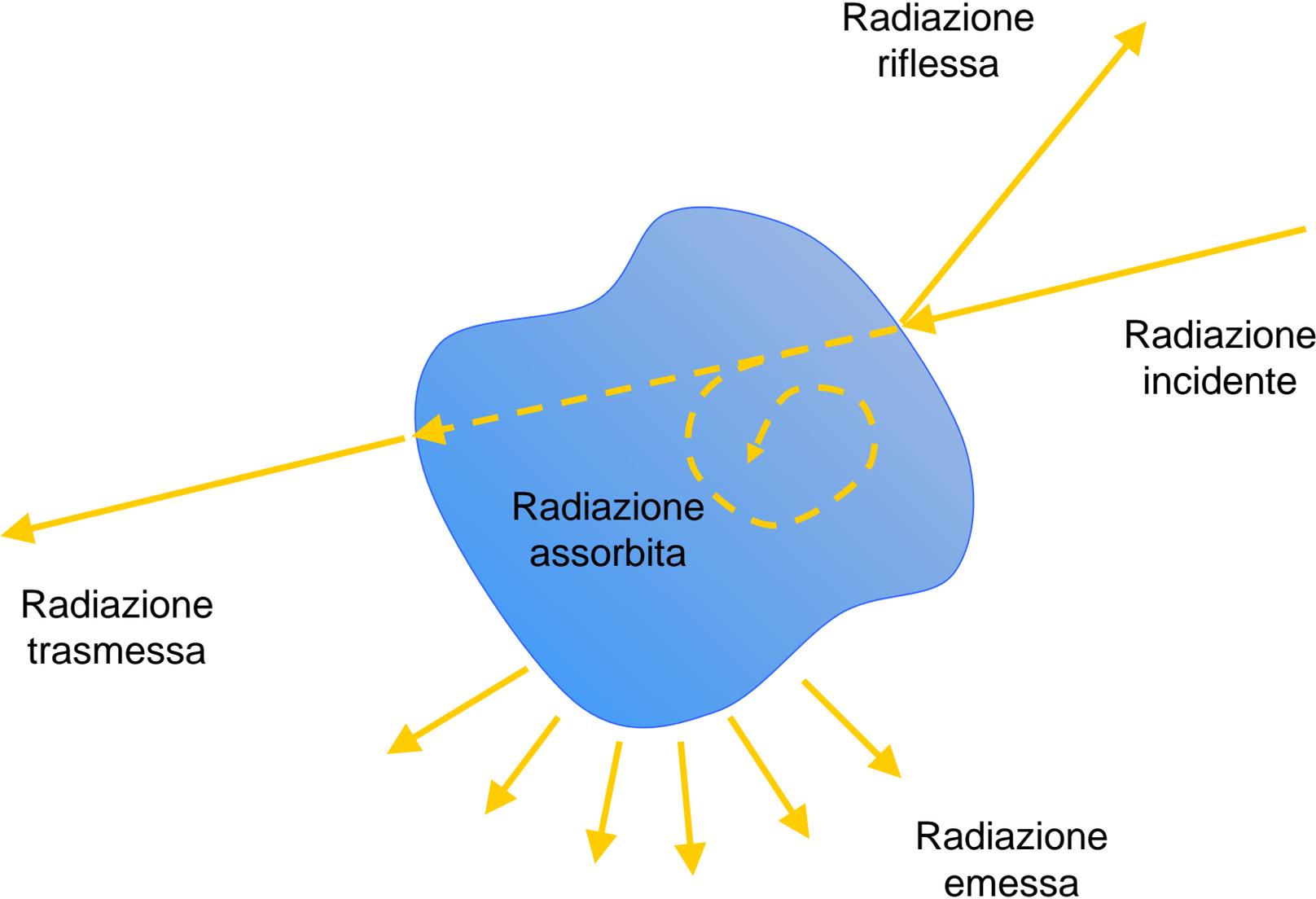


Figure 1.6 Boltzmann distribution of velocities for a molecular ensemble of oxygen atoms and hydrogen atoms. Escape velocity v_e for earth also indicated.

Onde elettromagnetiche e interazioni radiazione materia

Interazione radiazione-materia



Blackbody radiation

A *blackbody*⁴ is a surface that completely absorbs all incident radiation. Examples include certain substances such as coal and a small aperture of a much larger cavity. The entrances of most caves appear nearly black, even though the interior walls may be quite reflective, because only a very small fraction of the sunlight that enters is reflected back through the entrance: most of the light that enters the cave is absorbed in multiple reflections off the walls. The narrower the entrance and the more complex the interior geometry of the cave, the smaller the fraction of the incident light that is returned back through it, and the blacker the appearance of the cave when viewed from outside (Fig. 4.5).

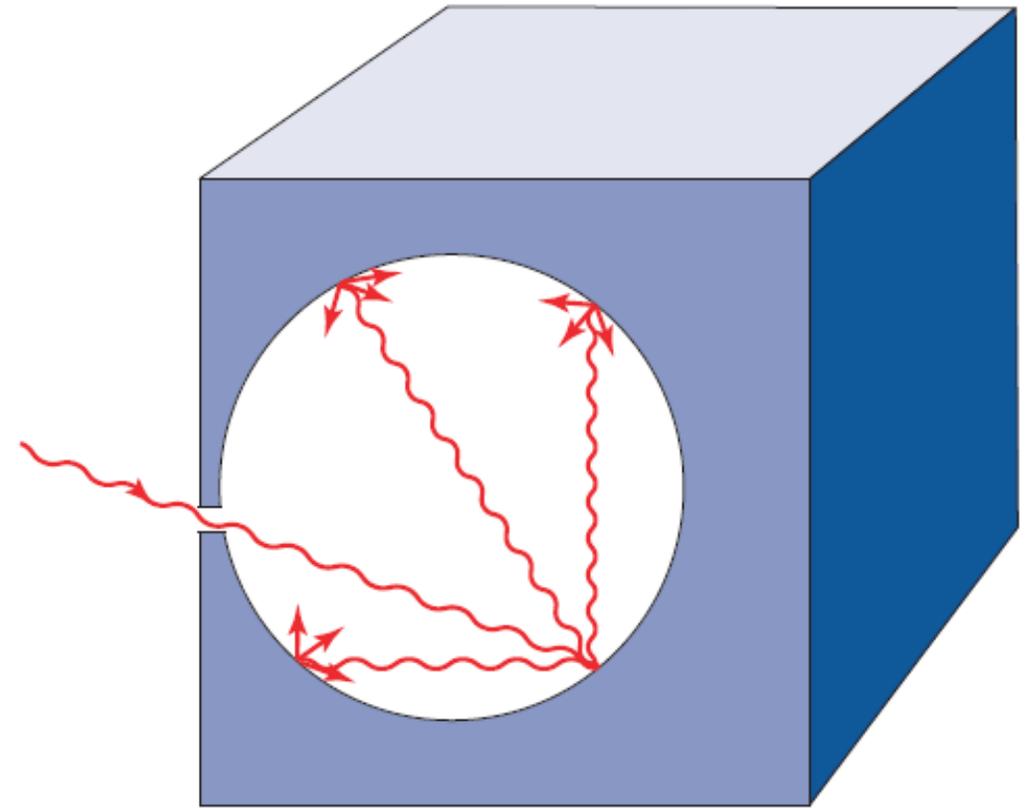


Fig. 4.5 Radiation entering a cavity with a very small aperture and reflecting off the interior walls. [Adapted from K. N. Liou, *An Introduction to Atmospheric Radiation*, Academic Press, p. 10, Copyright (2002), with permission from Elsevier.]

(Wallace and Hobbs 2006)

Plank's law

$$B_{\lambda}^* = \frac{c_1}{\lambda^5 \left[\exp\left(\frac{c_2}{\lambda T}\right) - 1 \right]}$$

$$c_1 = 2hc^* = 1.191 \cdot 10^{-16} \text{ W m}^{-2}$$

$$c_2 = \frac{hc^*}{k} = 1.44 \cdot 10^{-2} \text{ m K}$$

$$h = 6.6261 \cdot 10^{-34} \text{ m}^2 \text{ kg s}^{-1}$$

$$c^* = 2.998 \cdot 10^8 \text{ m s}^{-1}$$

$$k = 1.3806 \cdot 10^{-23} \text{ J K}^{-1}$$

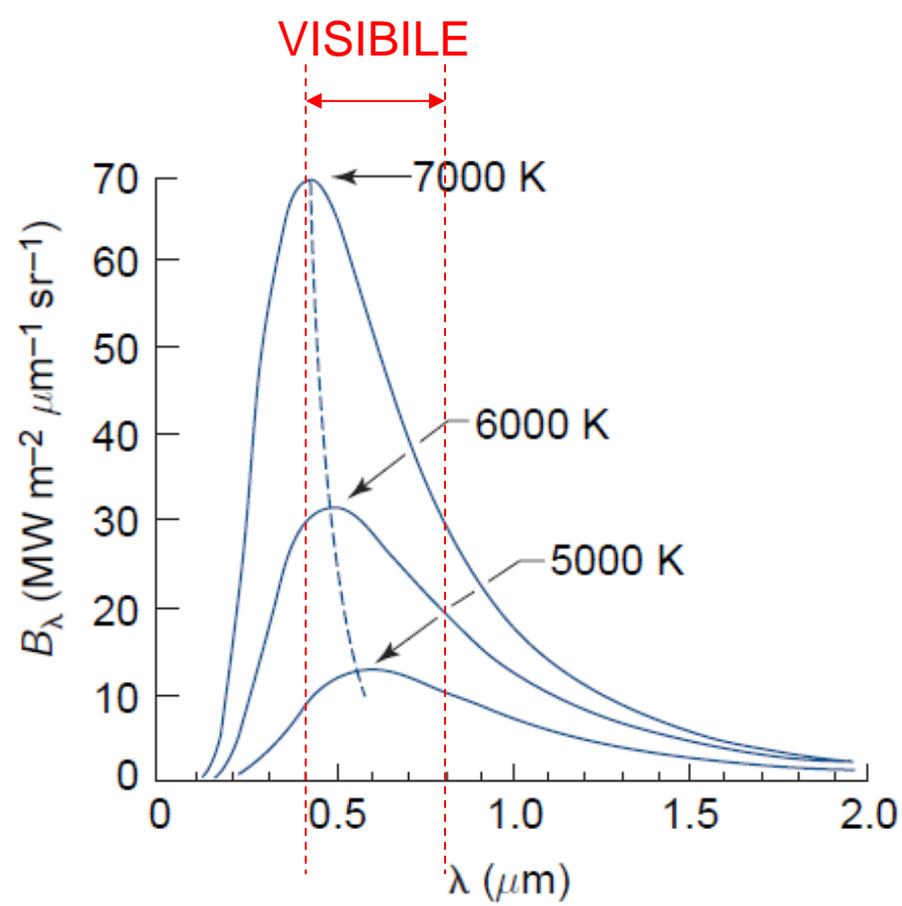


Fig. 4.6 Emission spectra for blackbodies with absolute temperatures as indicated, plotted as a function of wavelength on a linear scale. The three-dimensional surface formed by the ensemble of such spectra is the *Planck function*. [Adapted from R. G. Fleagle and J. A. Businger, *An Introduction to Atmospheric Physics*, Academic Press, p. 137, Copyright (1963) with permission from Elsevier.]

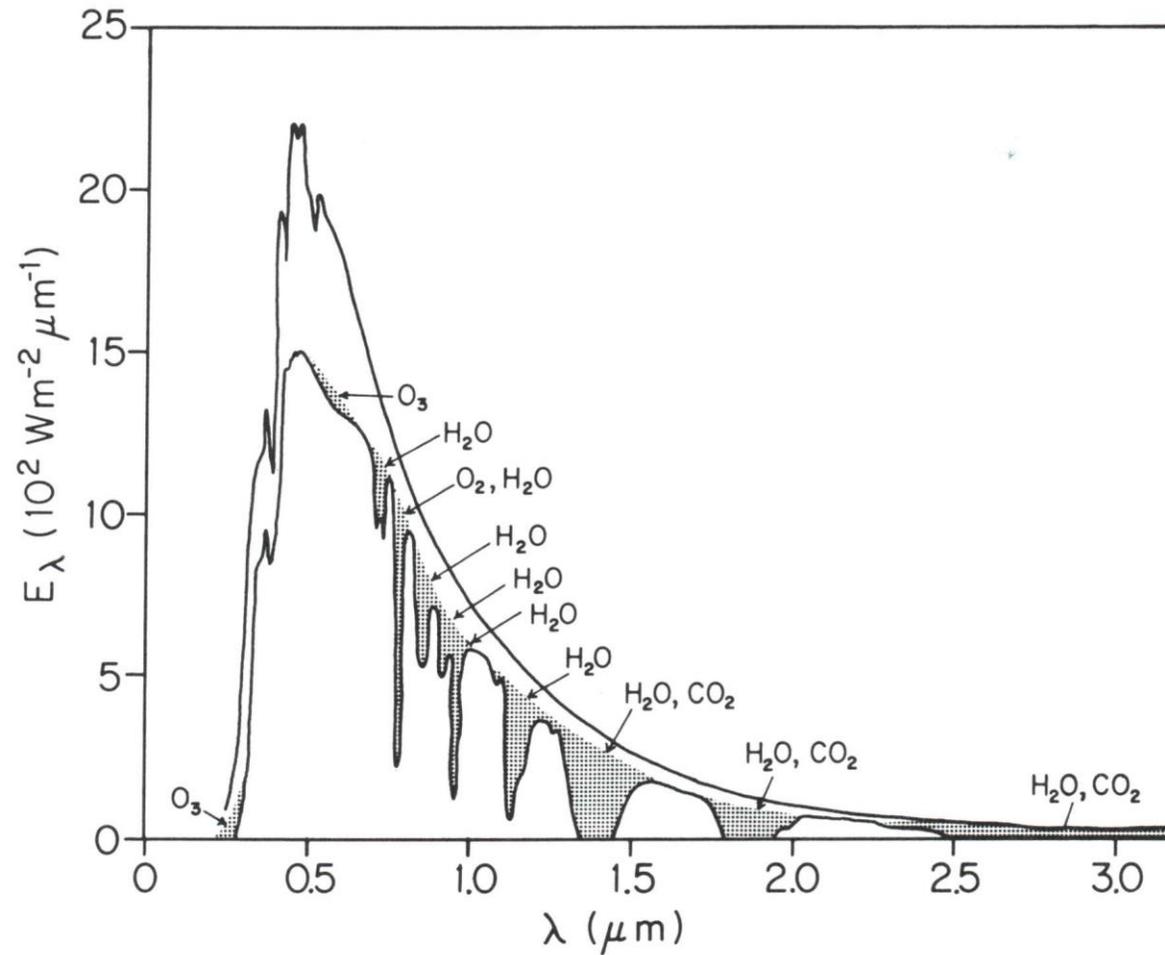


Fig. 7.7 Spectrum of solar radiation at the “top” of the atmosphere (upper curve) and at sea level (lower curve) for average atmospheric conditions and an overhead sun. The shaded area represents absorption by gaseous constituents, as indicated. [Adapted from “Handbook of Geophysics and Space Environments,” McGraw-Hill, New York (1965), p. 16–20.]

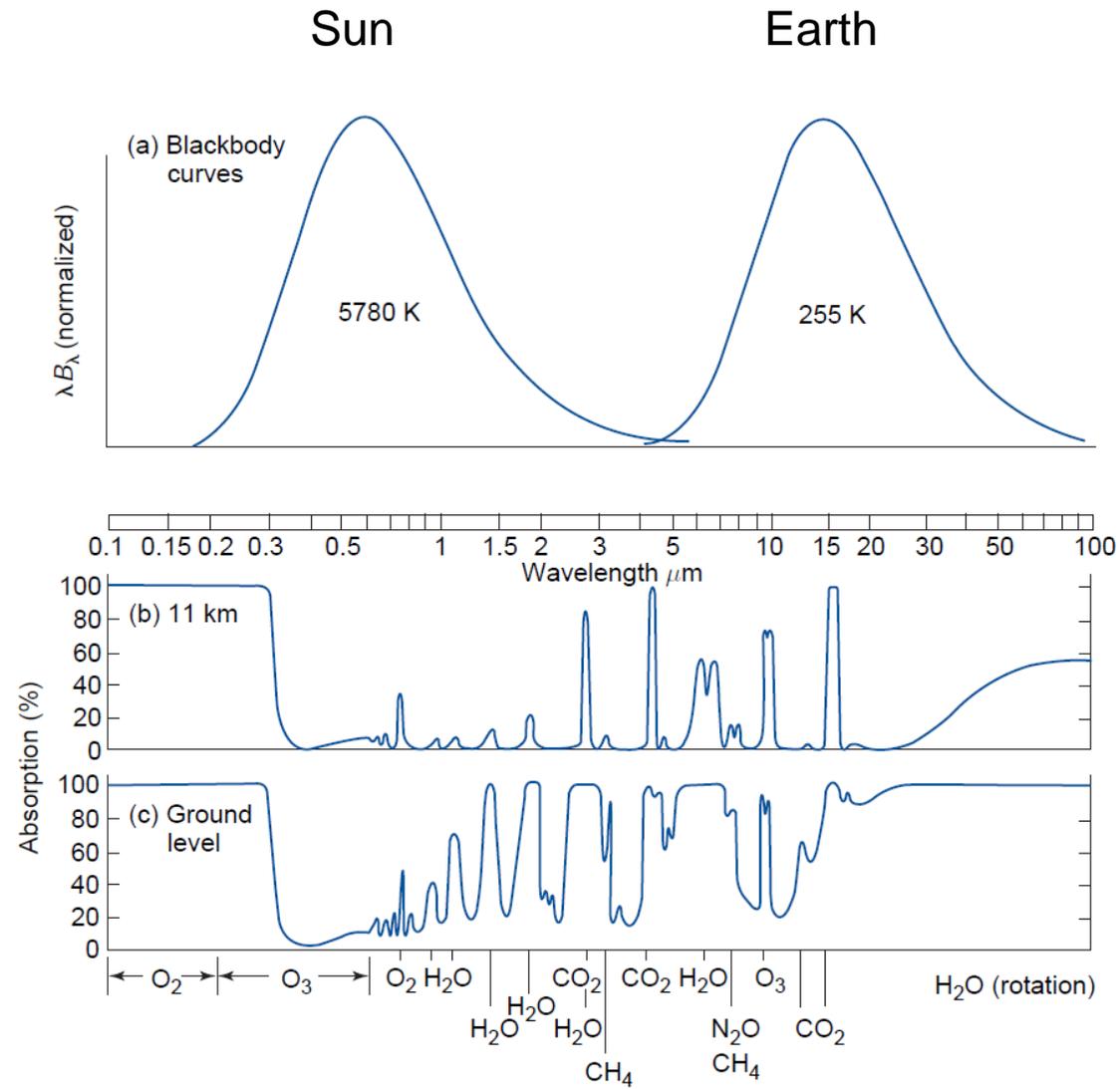
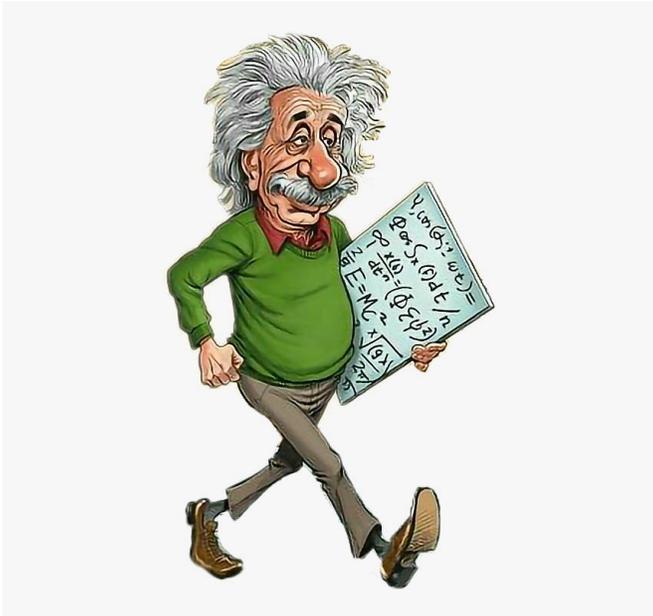
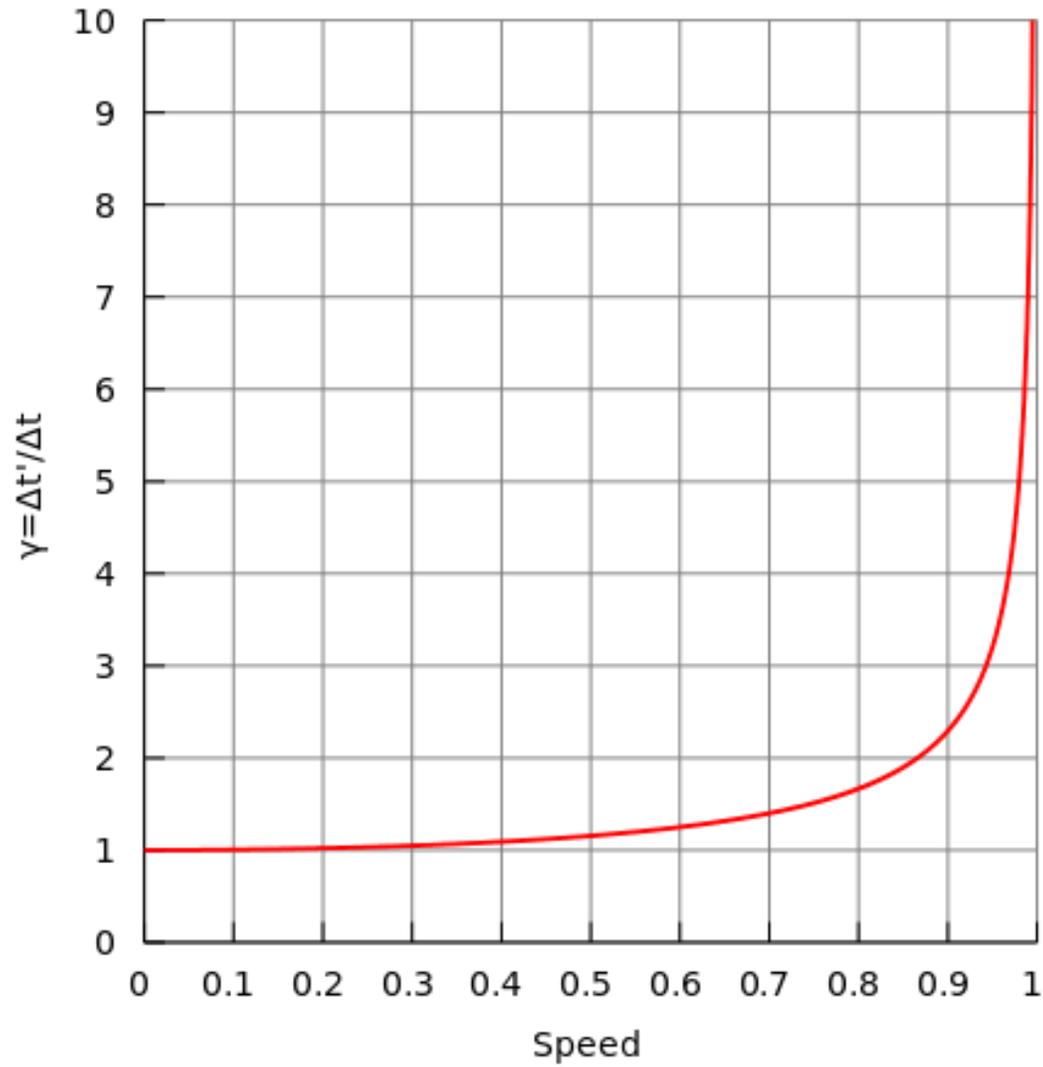


Fig. 4.7 (a) Blackbody spectra representative of the sun (left) and the Earth (right). The wavelength scale is logarithmic rather than linear as in Fig. 4.6, and the ordinate has been multiplied by wavelength in order to retain the proportionality between areas under the curve and intensity. In addition, the intensity scales for the two curves have been scaled to make the areas under the two curves the same; (b) Spectrum of monochromatic absorptivity of the part of the atmosphere that lies above the 11-km level; (c) spectrum of monochromatic absorptivity of the entire atmosphere. [From R. M. Goody and Y. L. Yung, *Atmospheric Radiation: Theoretical Basis*, 2nd ed., Oxford University Press (1995), p. 4. By permission of Oxford University Press, Inc.]

Effetti relativistici





Relation between the speed and the [Lorentz factor](#) $\gamma = \frac{1}{\sqrt{1 + \frac{v^2}{c^2}}}$ (and hence the time dilation of moving clocks).



A compact apparatus for muon lifetime measurement and time dilation demonstration in the undergraduate laboratory

Thomas Coan,^{a)} Tiankuan Liu,^{b)} and Jingbo Ye^{c)}
Physics Department, Southern Methodist University, Dallas, Texas 75275

(Received 22 February 2005; accepted 14 October 2005)

We describe a compact apparatus for measuring the charge-averaged lifetime of atmospheric muons in plastic scintillator using low-cost, low-power electronics. We present measurements of the stopping rate of atmospheric muons as a function of altitude to demonstrate relativistic time dilation. The apparatus is designed for the advanced undergraduate physics laboratory and is suitable for field measurements. © 2006 American Association of Physics Teachers.

[DOI: 10.1119/1.2135319]

<https://doi.org/10.1119/1.2135319>

Fisica nucleare



The hydrogen contained in water molecules



DECIPHER

Disentangling mechanisms controlling atmospheric transport and mixing processes over mountain areas at different space- and timescales.

2023 - 2025



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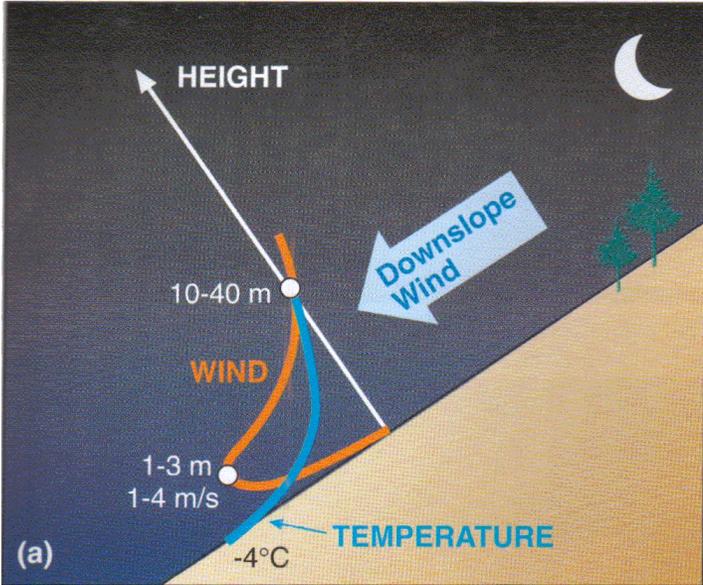
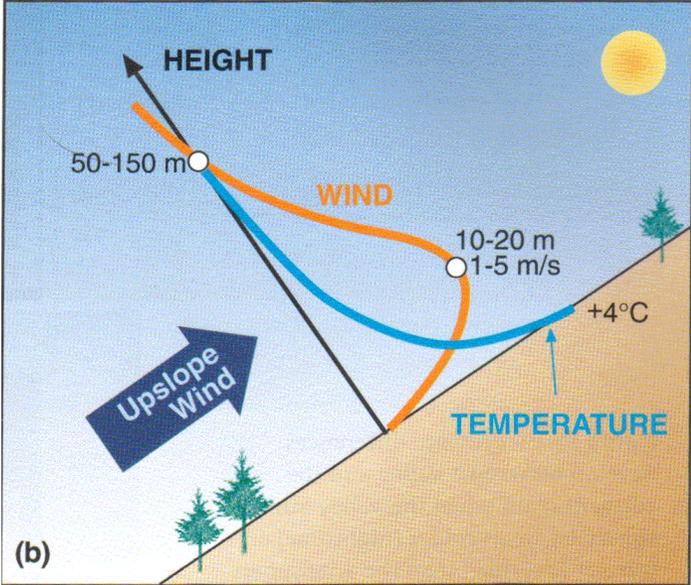


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Slope winds

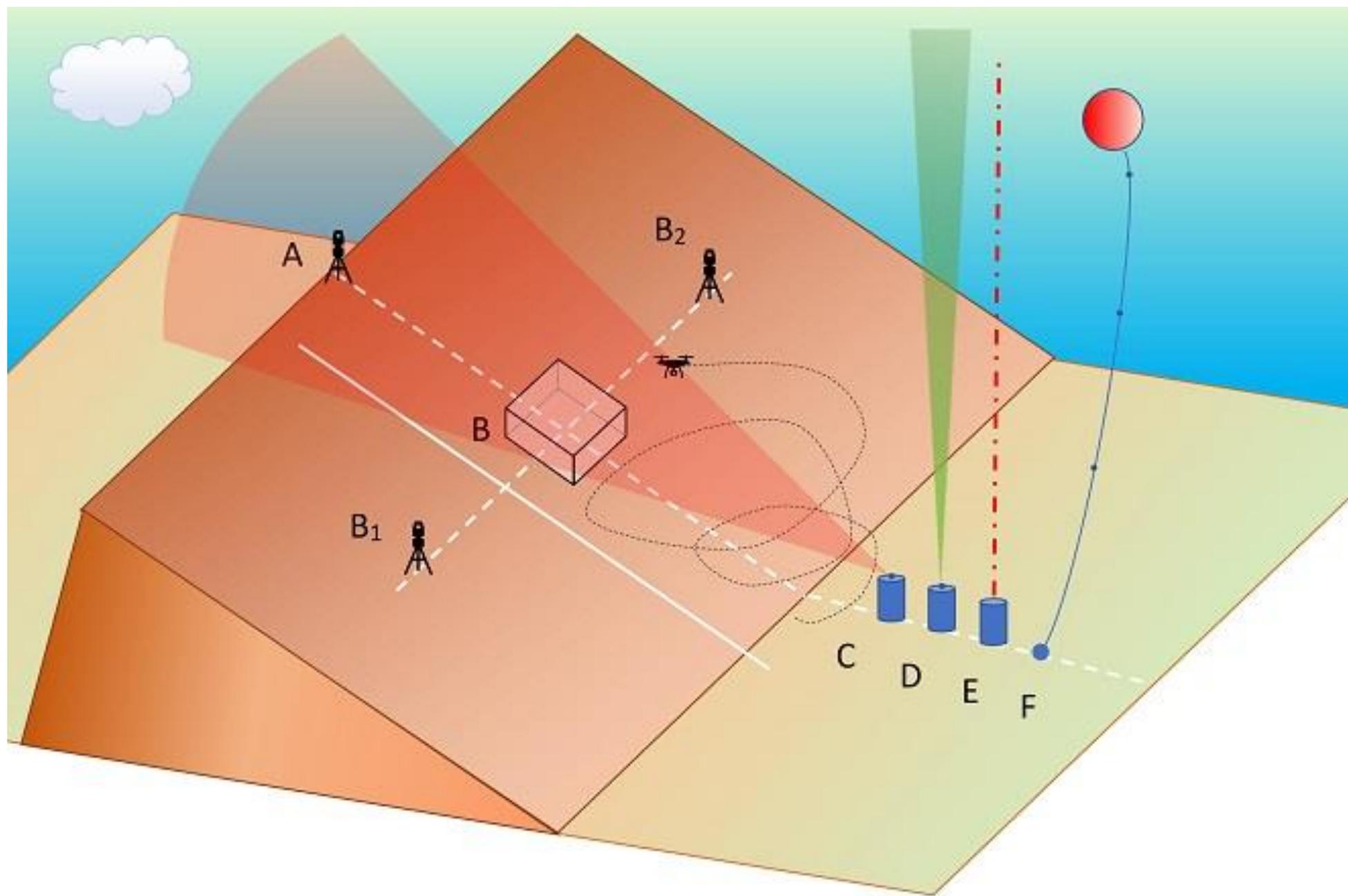
Up-slope winds

Down-slope winds



Dave Whiteman

(Whiteman, 2000)





Rovereto

14-17 Novembre 2024

10^a edizione

www.festivalmeteorologia.it





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DI TRENTO



DOUBLE-DEGREE MSc PROGRAMME IN ENVIRONMENTAL METEOROLOGY



Il progetto Cli-DaRe@School: un bilancio di due anni di attività con le scuole

Maurizio Maugeri

Department of Environmental Science and Policy

Università degli Studi di Milano

maurizio.maugeri@unimi.it



Rovereto – 15 novembre 2024



PREMESSA: PERCHÈ CI SERVONO LUNGHE SERIE DI DATI METEOROLOGICI?

Il clima è una risorsa fondamentale del territorio
(un esempio per le piogge)

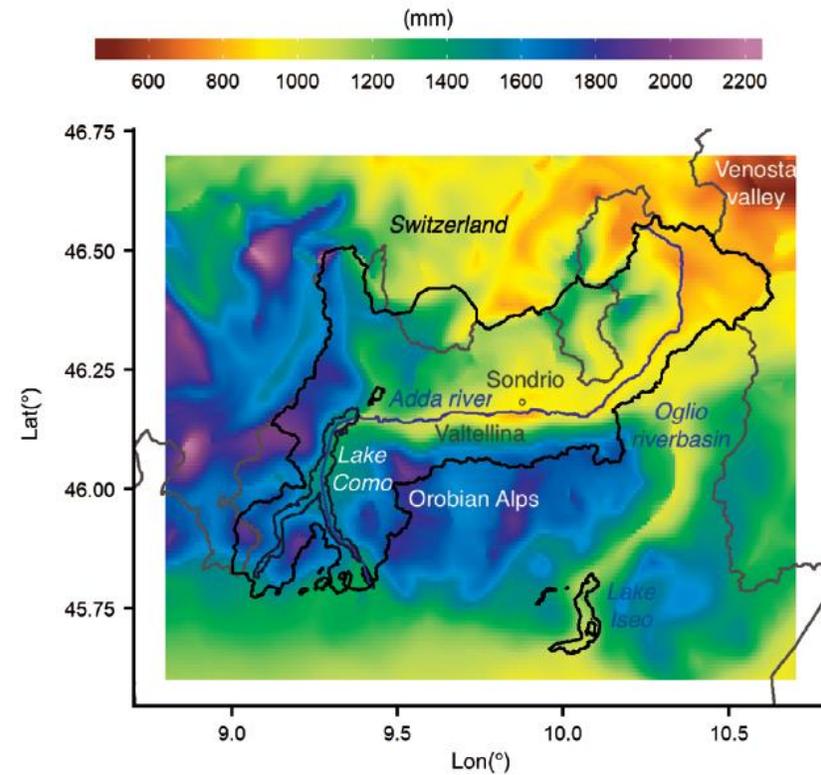


FIGURE 4 1961–1990 annual precipitation climatologies

...PERCHÈ LUNGHE SERIE DI DATI METEO...

Il clima può cambiare nel tempo

Per le piogge possono, per esempio, cambiare:

I valori normali (cioè può piovere di più o di meno in un certo periodo di tempo come, per esempio, un anno);

Il numero di giorni piovosi;

La pioggia che mediamente si ha in ogni giorno piovoso.

In un Paese molto esposto a fenomeni alluvionali come l'Italia è molto importante capire se con il global warming si sia osservata una più elevata frequenza di eventi precipitativi di forte intensità.

Allo stesso modo è importante capire se si abbiano tendenze negli eventi estremi opposti, ovvero nei lunghi periodi caratterizzati dall'assenza di precipitazioni.

...PERCHÈ LUNGHE SERIE DI DATI METEO...

Il clima può cambiare nel tempo

Per le temperature possono, per esempio, cambiare:

I valori normali (cioè può fare mediamente più o meno caldo);

Il ciclo stagionale;

La variabilità da un giorno all'altro.

È anche molto importante capire se con il global warming si sia osservato un cambiamento nella forma delle distribuzioni di probabilità delle temperature (a scala giornaliera, mensile, stagionale e annuale).

È infine importante capire quali siano i segnali di cambiamento per gli eventi estremi, ovvero le forte ondate di calore e/o gli episodi molto freddi.

È quindi assolutamente chiaro perché esista una grande «fame» di lunghe serie di dati meteorologici da parte di svariati settori della società

E la disponibilità di questi dati è spesso ancora molto ad di sotto di ciò che sarebbe desiderabile, con molti dati ancora disponibili solo su carta



In questo contesto, nel 2022, nasce il Progetto Cli-DaRe – Citizen Science for Italian Climate Data Rescue



<https://aisam.eu/progetti/cli-dare/>

L'obiettivo del progetto è quello di avviare un percorso di lungo termine che consenta di valorizzare l'enorme potenziale della Citizen Science per il recupero dei molti dati meteorologici raccolti in Italia nel passato, che rimangono ancora confinati solo in archivi cartacei.

Il progetto mira sia alla scansione degli archivi cartacei che alla successiva trascrizione delle serie delle variabili meteorologiche a partire dalle immagini digitali.

L'obiettivo finale è quello di rendere disponibile un archivio digitale delle antiche osservazioni meteorologiche del nostro Paese, sia come immagini degli antichi volumi, sia come dati fruibili per la ricerca scientifica.

Il progetto Cli-DaRe è attivo da poco più di due anni e questa mattina vedremo le principali attraverso le quali esso si è sviluppato.

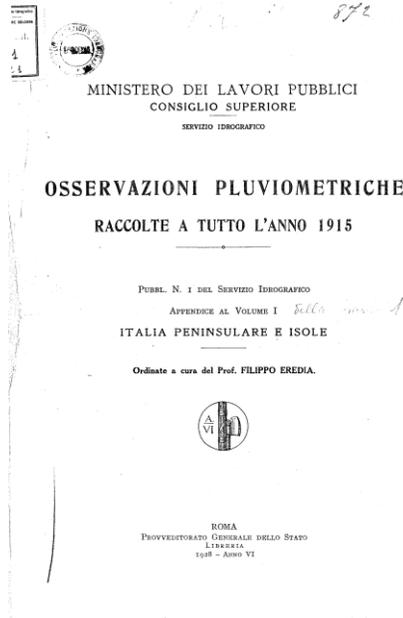
La prima iniziativa che vediamo insieme è:

Cli-DaRe@School - Students for Italian Climate Data Rescue

Questa iniziativa si è avviata nell'a.s. 2022/23 e si è poi sviluppata anche nell'a.s. 2023/24, mentre nel corrente a.s. le attività con le scuole, ovvero quelle volte alla trascrizione delle serie delle variabili meteorologiche a partire dalle immagini digitali, sono in una fase di pausa perché tutte le nostre energie sono rivolte alla scansione di nuovi archivi cartacei contenenti i dati delle ex colonie italiane.

Gli studenti coinvolti finora sono circa 500

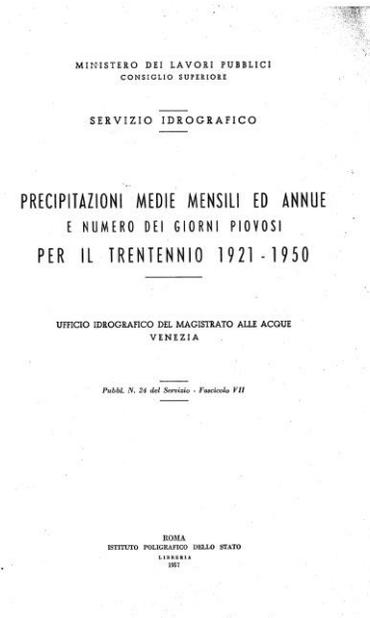
Quali sono i dati che abbiamo digitalizzato?



3 volumi



3 volumi



14 volumi



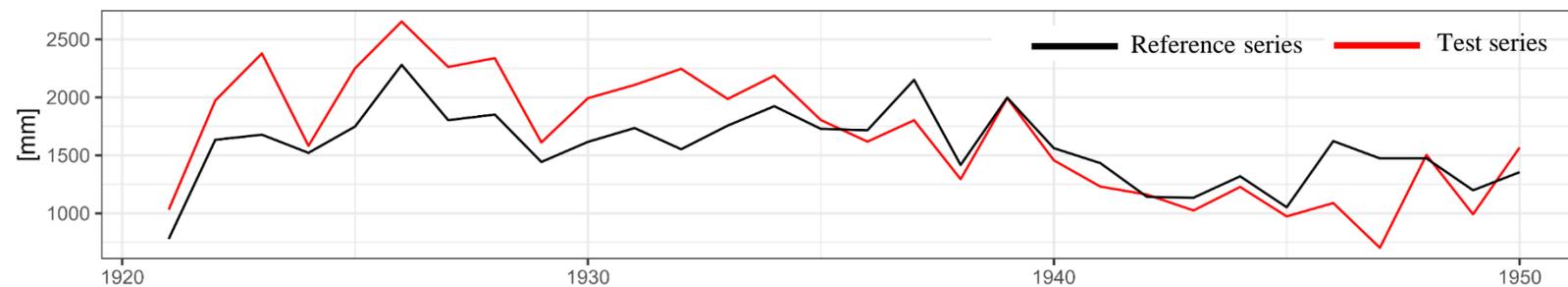
3 volumi

Registri dell'Osservatorio dell'Osservatorio Meteo di Mantova

Due moduli dedicati all'approfondimento di aspetti chiave del data rescue:

- l'esigenza di definire accuratamente la posizione delle vecchie osservazioni
- l'esigenza di verificare l'omogeneità delle serie digitate

Moduli specifici, offerti a richiesta, su altri temi come, per esempio, l'analisi delle serie temporali



Un ciclo di sette seminari



Alessandro Ceppi - La stazione meteorologica.pdf



Alessandro Ceppi - Meteorologia e climatologia.pdf



Daniele Cat Berro - Quali sono le soluzioni al cambiamento climatico.pdf



Dino Zardi - Prevedere il tempo, prevedere il clima.pdf



Francesco Sudati - La meteorologia operativa.pdf



Maurizio Maugeri - L'impronta climatica di ognuno di noi.pdf



Michele Brunetti - Il clima che cambia... anzi, è già cambiato!.pdf

... qualche feedback ...

... dalla comunità scientifica ...

Bulletin of the American Meteorological Society
Engaging high-school students in rescuing and digitizing data from historical
observations in Italy: the citizen-science project Cli-DaRe@School
--Manuscript Draft--

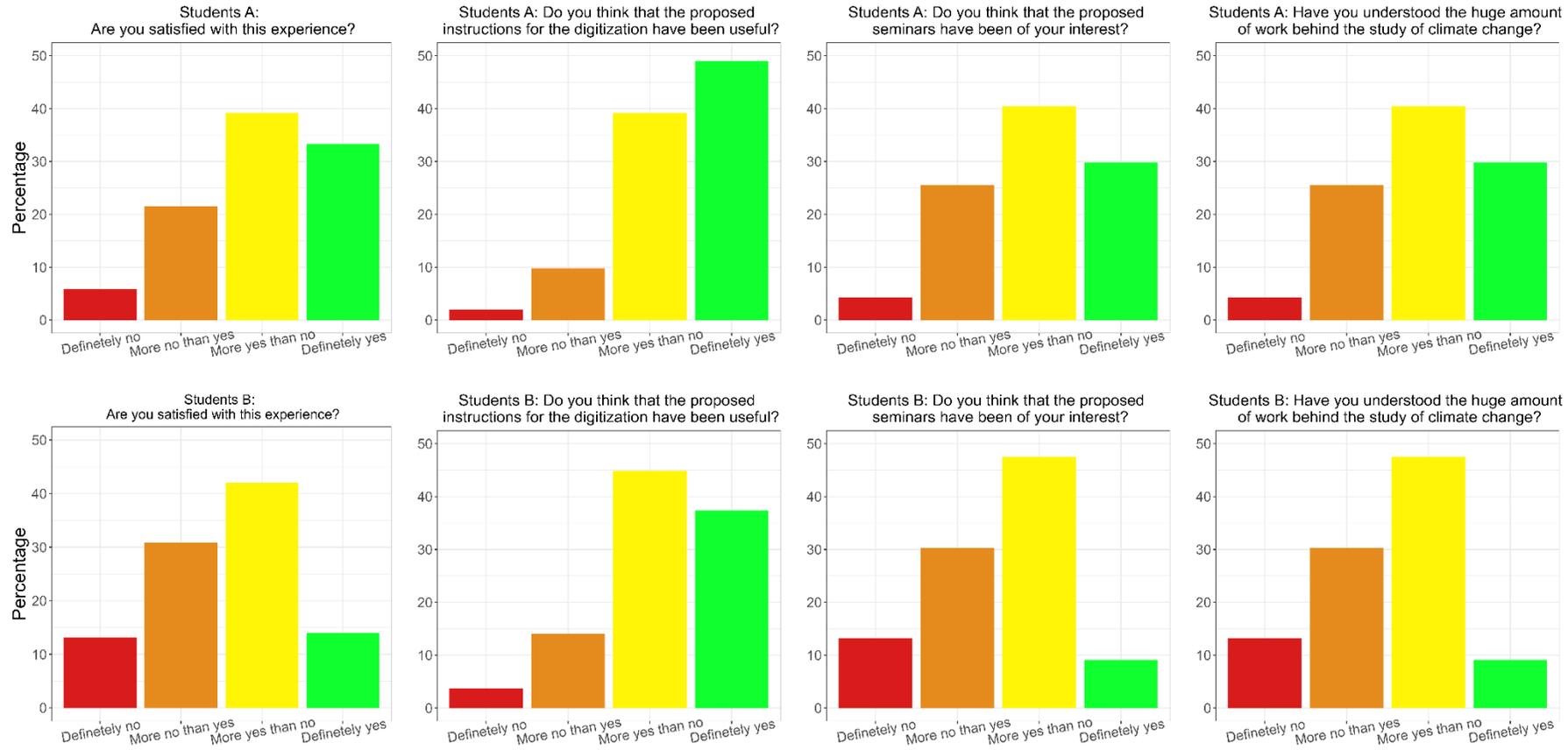
Manuscript Number:	BAMS-D-24-0078
Full Title:	Engaging high-school students in rescuing and digitizing data from historical observations in Italy: the citizen-science project Cli-DaRe@School

Reviewer #1 ... this is indeed a very interesting paper and a very important topic ...

Reviewer #2 ... this manuscript describes a highly promising initiative that not only focuses on recovering climate data from archives but also actively engages students in climate science ...

Reviewer #3: ... this was absolutely wonderful work ...

... dagli studenti...



... dagli insegnanti ...



**Grazie
per la vostra
attenzione!**

dino.zardi@unitn.it