Laurea in Ingegneria per l'Ambiente ed il Territorio

CAMBIAMENTI CLIMATICI E ADATTAMENTI NEGLI ECOSISTEMI E NELLE SOCIETÀ

Docenti

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Supporto didattico
Edoardo Crescini

- 6 CFU
- 48 ore
- 102 ore di studio individuale

Outline

- Biomi e clima
- Classificazione dei climi
- Il sistema Koppen
- Impatti

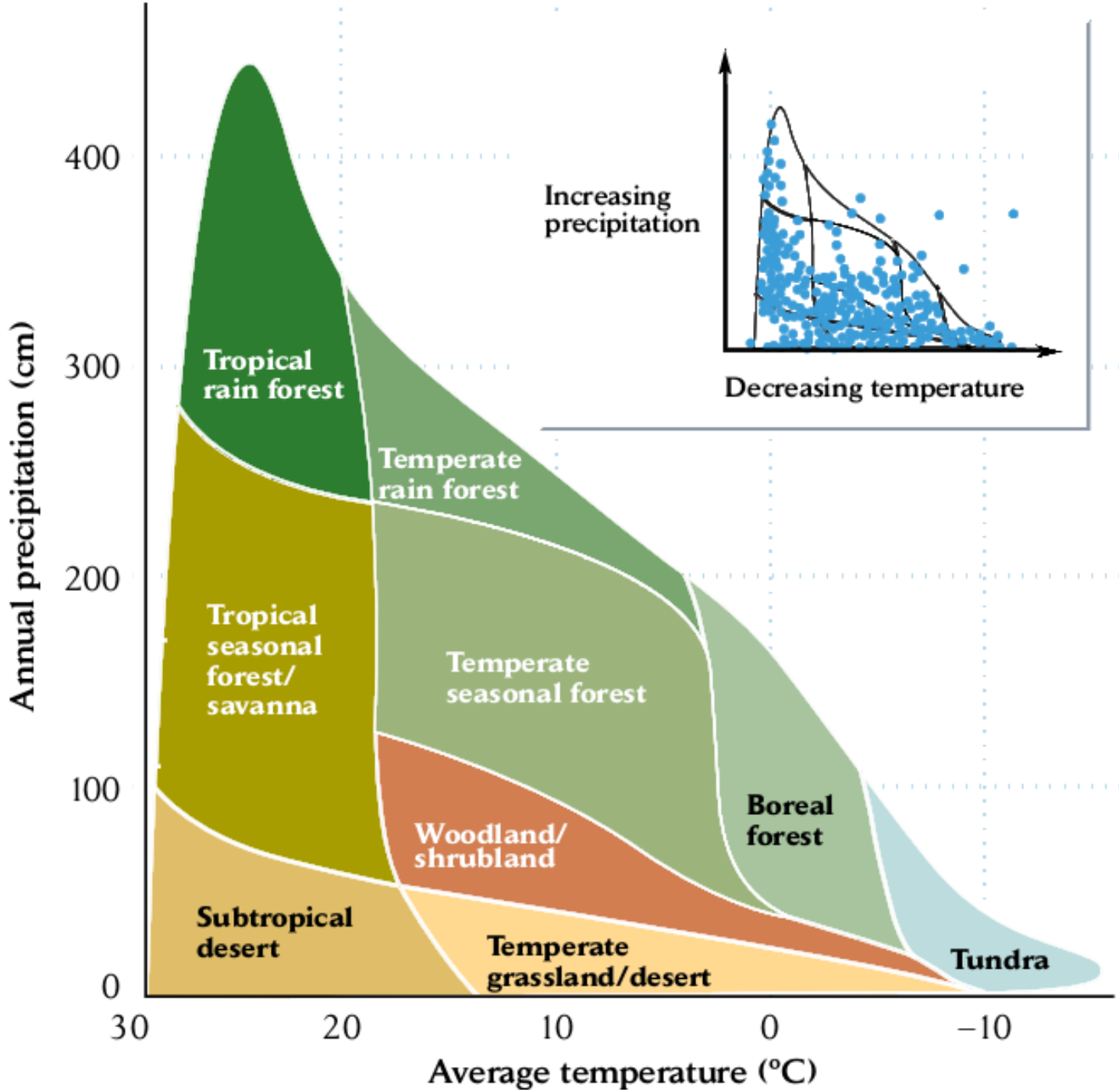
Clima e biomi

Whittaker's System Classification Different Biomes

Biome name	Climate zone			Vegetation
Tropical rain forest	I	Equatorial:	Always moist and lacking temperature seasonality	Evergreen tropical rain forest
Tropical seasonal forest/ savanna	II	Tropical:	Summer rainy season and "winter" dry season	Seasonal forest, scrub, or savanna
Subtropical desert	III	Subtropical (hot deserts):	Highly seasonal, arid climate	Desert vegetation with considerable exposed surface
Woodland/shrubland	IV	Mediterranean:	Winter rainy season and summer drought	Sclerophyllous (drought-adapted), frost-sensitive shrublands and woodlands
Temperate rain forest	V	Warm temperate:	Occasional frost, often with summer rainfall maximum	Temperate evergreen forest, somewhat frost-sensitive
Temperate seasonal forest	VI	Nemoral:	Moderate climate with winter freezing	Frost-resistant, decidous, temperate forest
Temperate grassland/ desert	VII	Continental (cold deserts):	Arid, with warm or hot summers and cold winters	Grasslands and temperate deserts
Boreal forest	VIII	Boreal:	Cold temperate with cool summers and long winters	Evergreen, frost-hardy needle-leaved forest (taiga)
Tundra	IX	Polar:	Very short, cool summers and long, very cold winters	Low, evergreen vegetation, without trees, growing over permanently frozen soils

Figure 5.4 Heinrich Walter classified the climate zones of the world according to the annual cycle of temperature and precipitation. The biome names given to these zones under Whittaker's classification scheme are shown in the left-hand column.

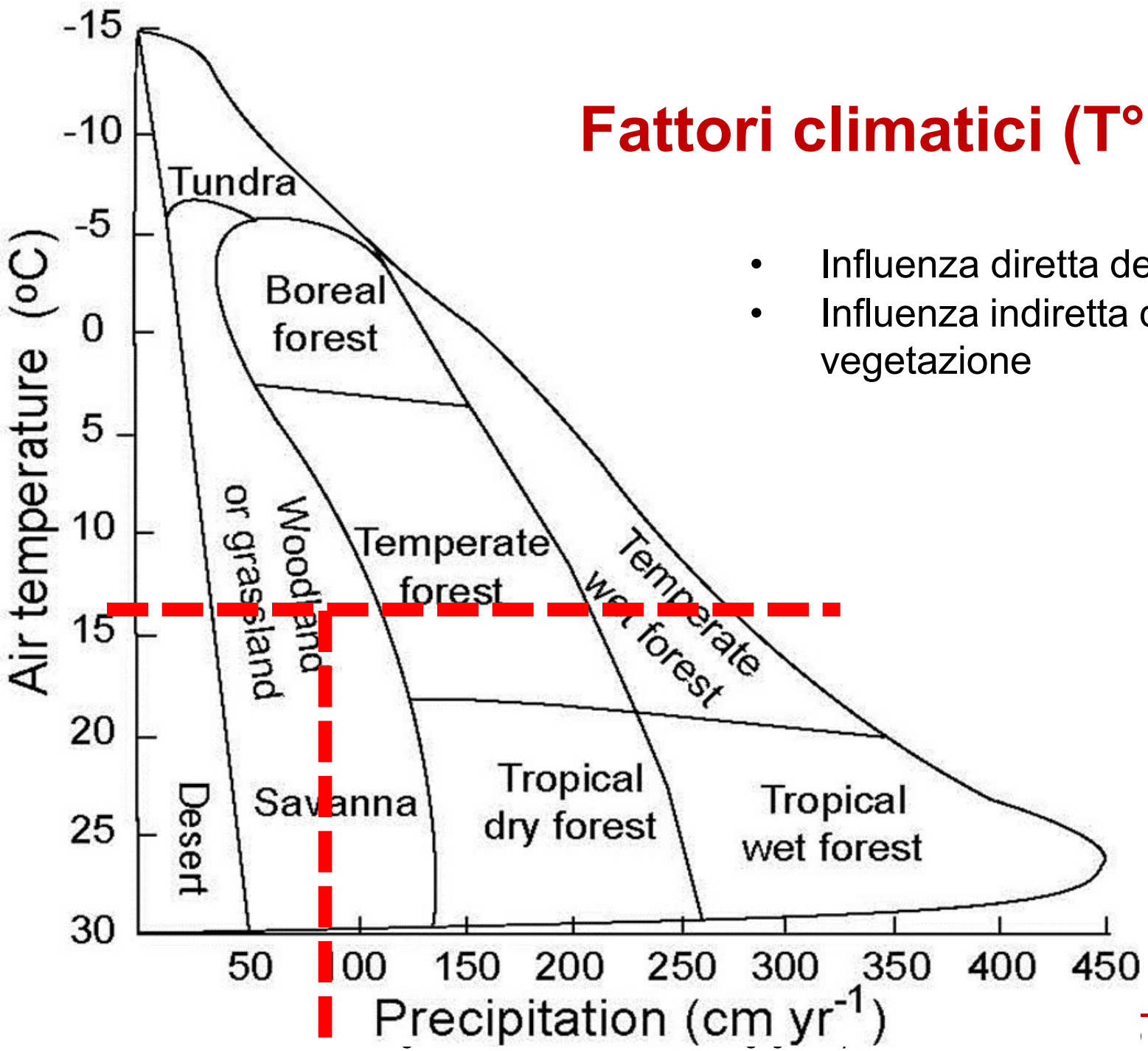
Figure 5.5 Whittaker's biomes are delineated according to average temperature and precipitation. Whittaker plotted the boundaries of observed vegetation types with respect to average temperature and precipitation. In climates intermediate between those of forest and desert biomes, climatic seasonality, fire, and soils determine whether woodland, grassland, or shrubland develops. *Inset:* average annual temperature and precipitation for a sample of localities more or less evenly distributed over the land area of the earth. Most of the points fall within a triangular region that includes almost the full range of climates. Only the climates of high mountains do not fall within the triangle. From r . h . Whittaker, *Communities and Ecosystems,* 2nd ed., Macmillan, New York (1975).



Fattori climatici e biomi

Fattori climatici (T° e pioggia) e biomi

- Influenza diretta della precipitazione
- Influenza indiretta della temperatura sulla fisiologia della vegetazione



Principali fattori climatici

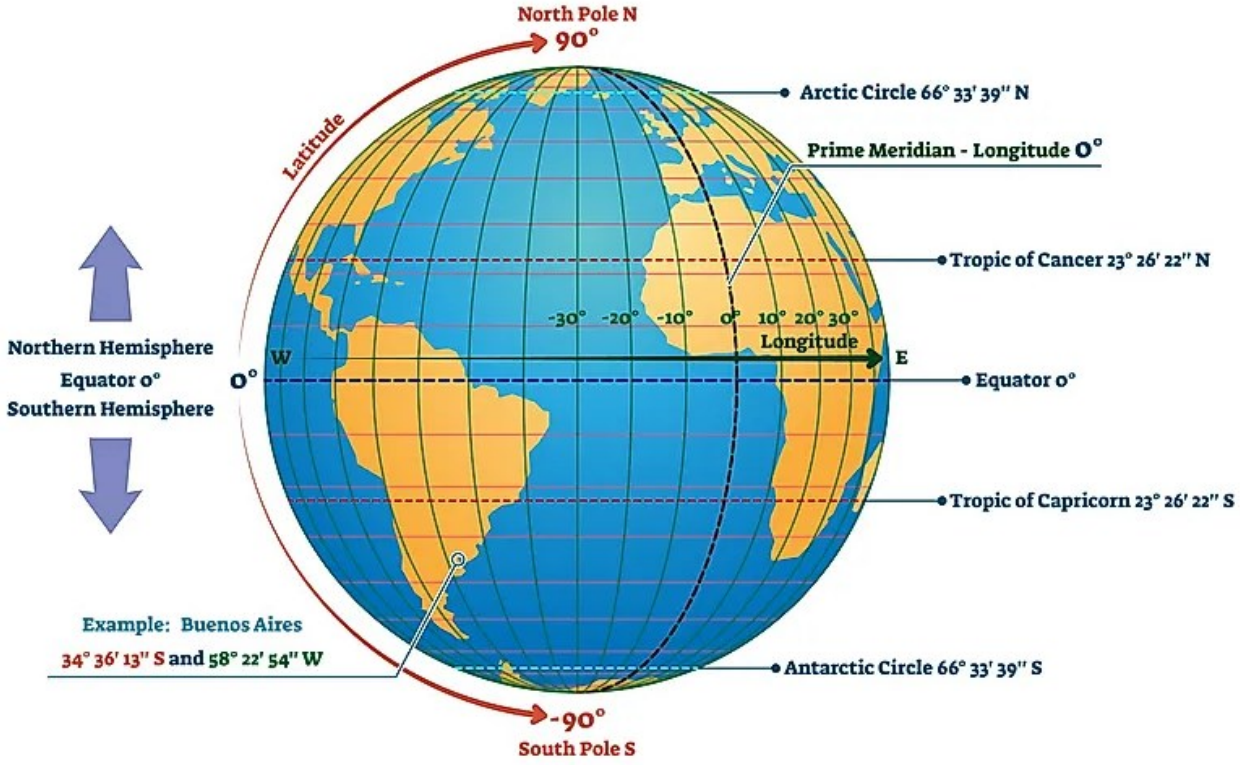
1. Latitudine e stagionalità
2. Elevazione (altitudine)
3. Geografia fisica e topografia (sistema orogenetico e distribuzione delle terre emerse e oceani)
4. Circolazione generale atmosferica
5. Circolazione generale degli oceani

…e le loro interazioni!

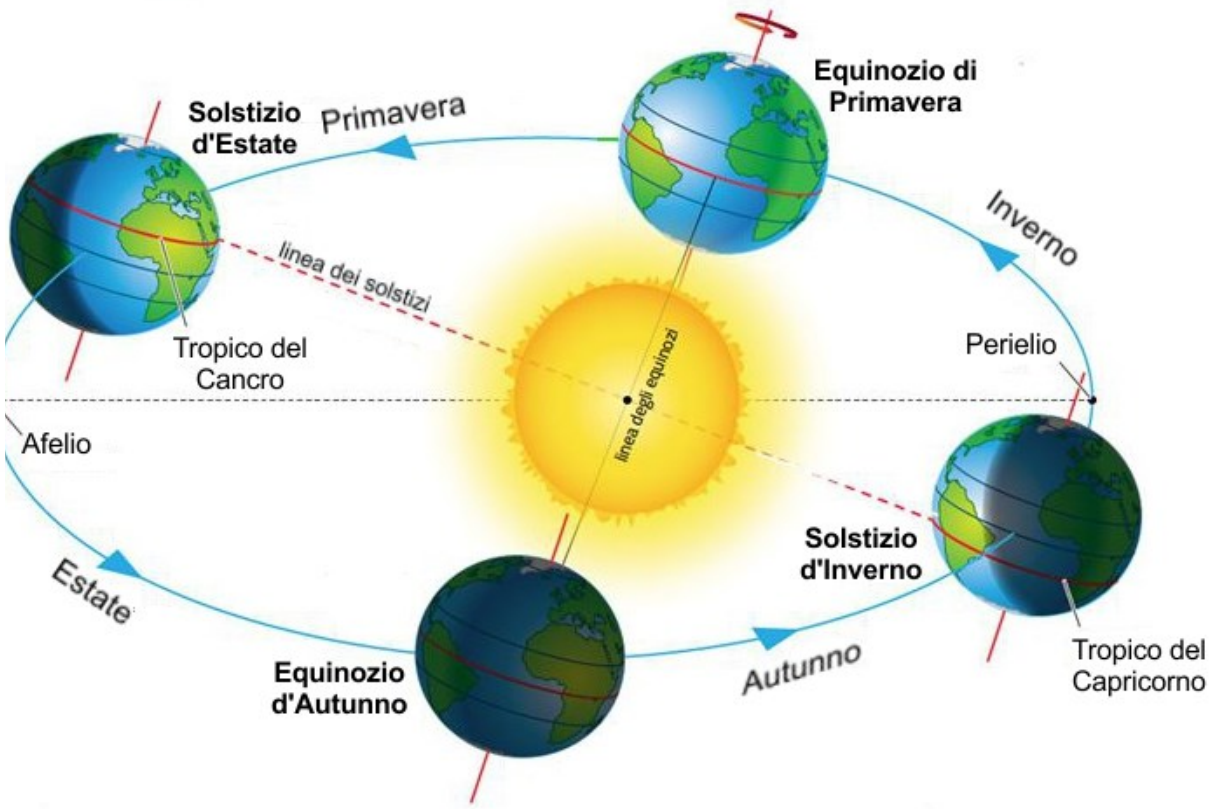
Fattori climatici: insolazione

Radiazione solare e geometria orbitale

Latitudine



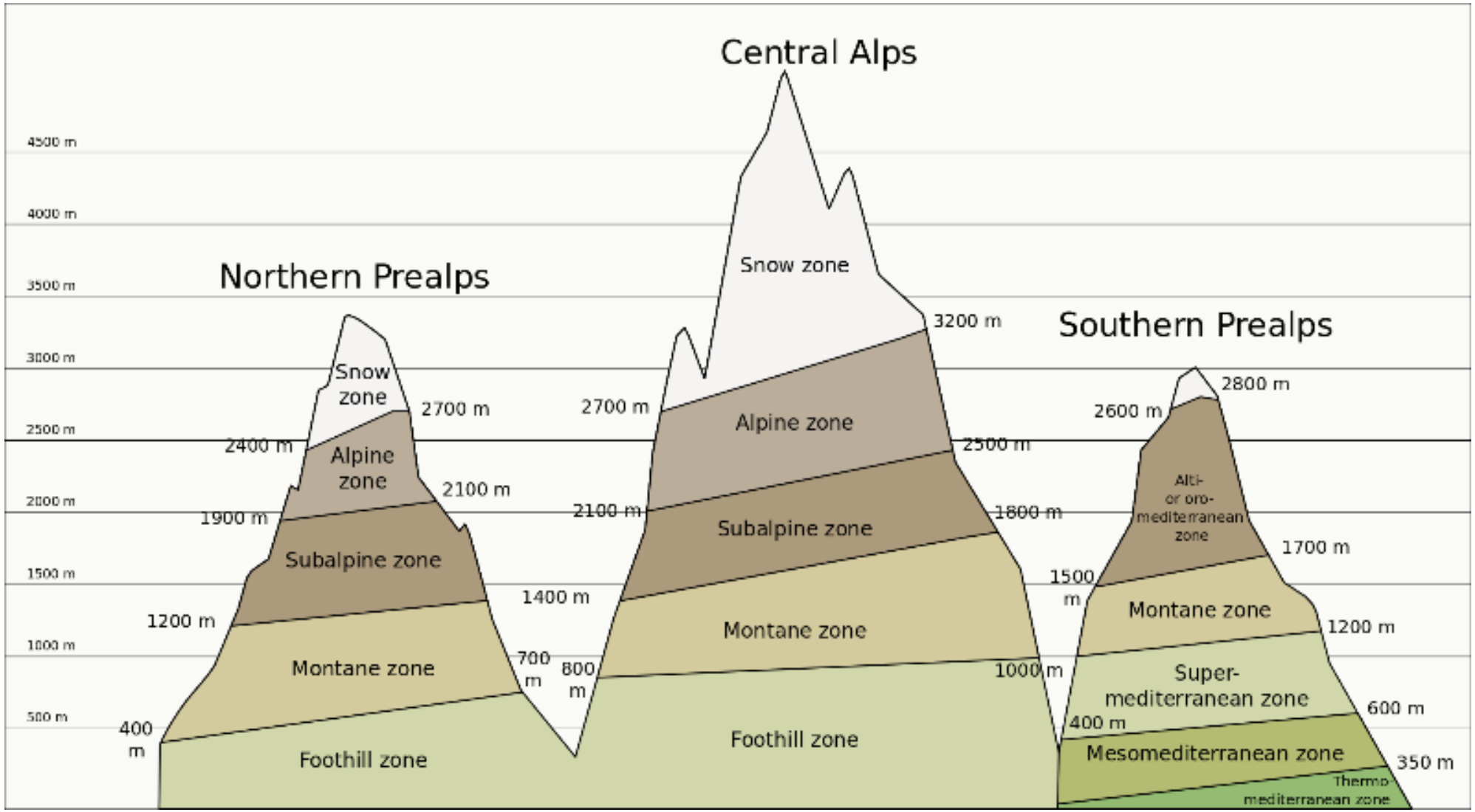
Stagionalità

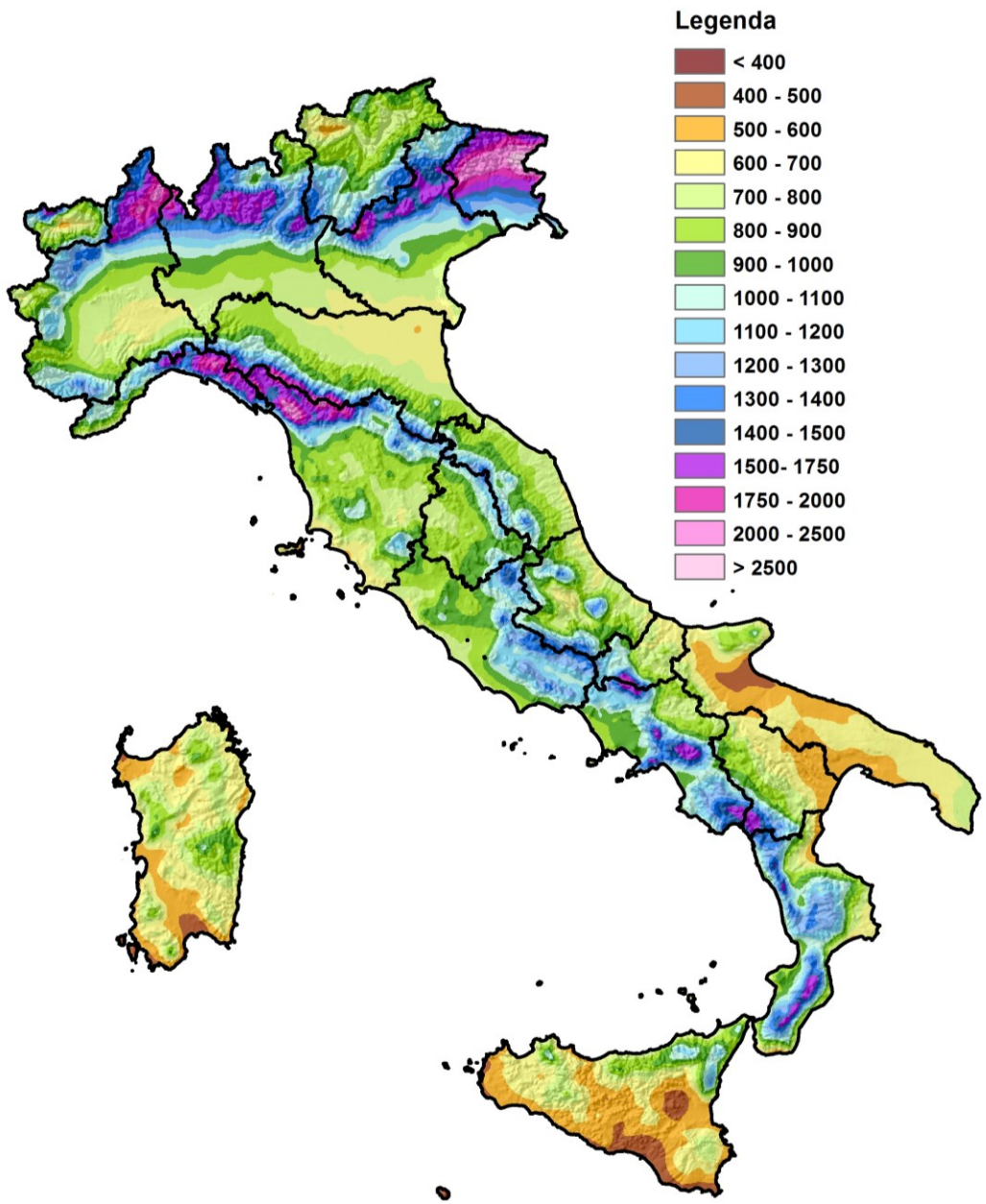


https://www.worldatlas.com/geography/latitude-and-longitude.html
https://articomostra.cnr.it/index.php/finale-2-ofcv/cosa-provvoca-le-stagioni-ofcv

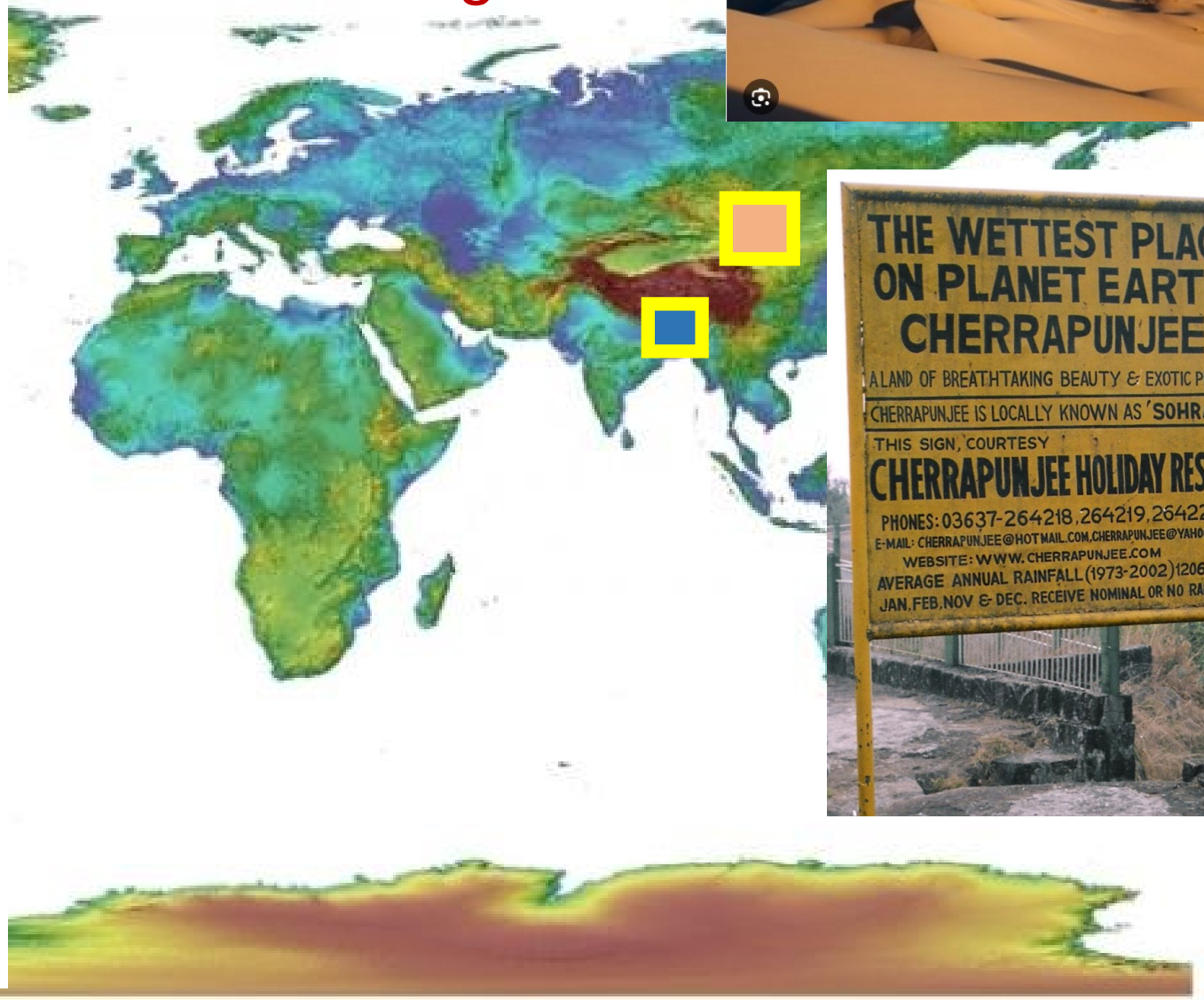
Fattori climatici

Elevazione (altitudine)



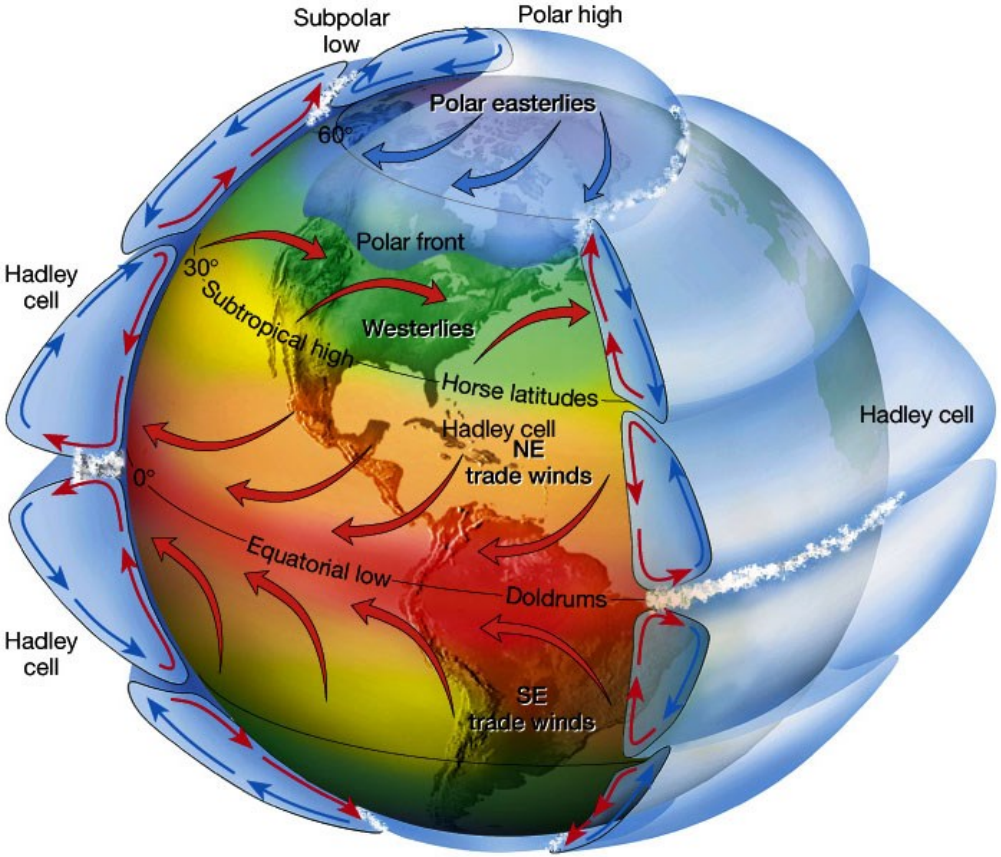


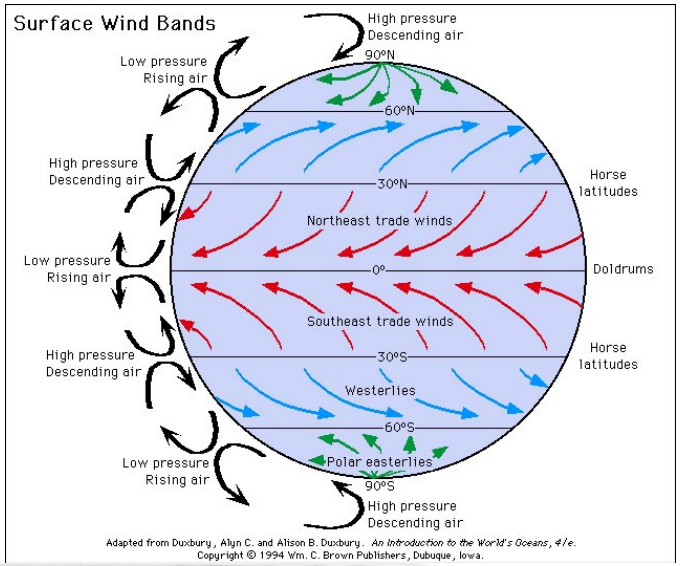
a e sistema orogenetico

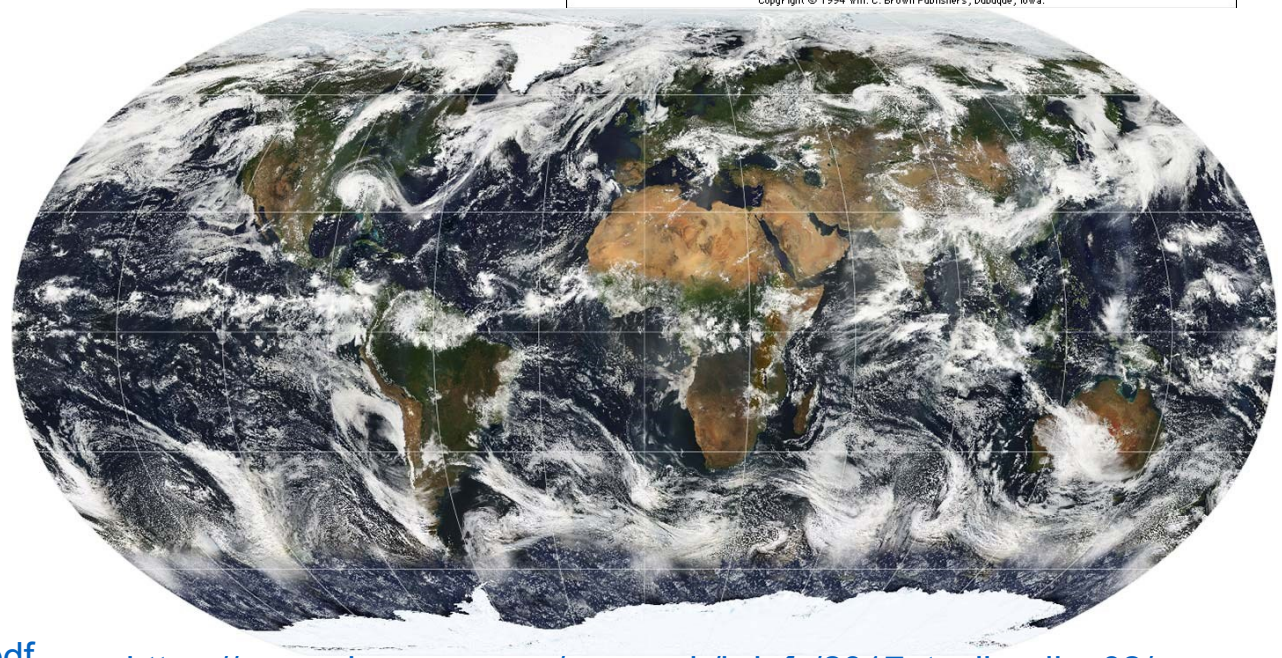


https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-global-multi-resolution-terrain-elevation#publications

Circolazione generale atmosferica



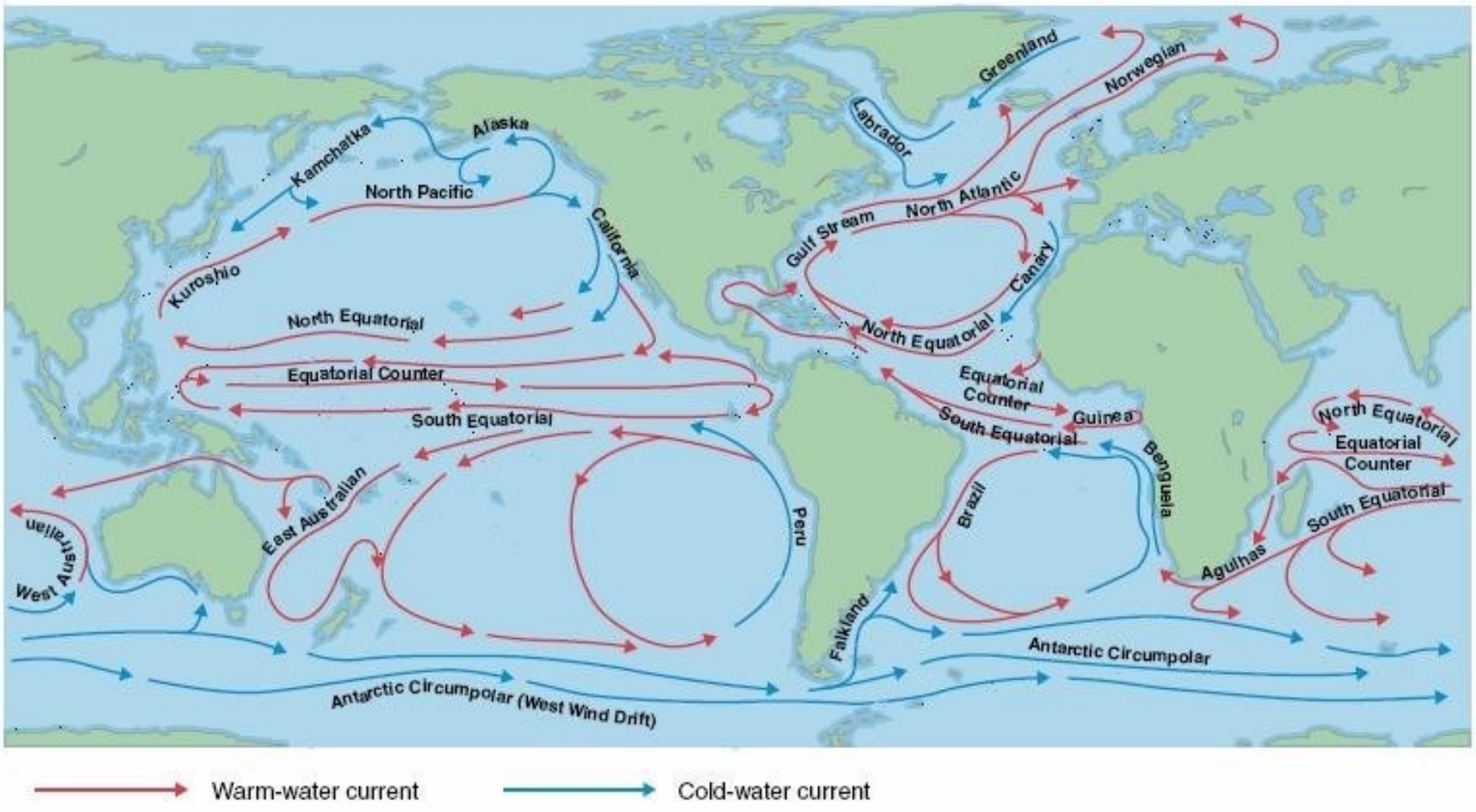


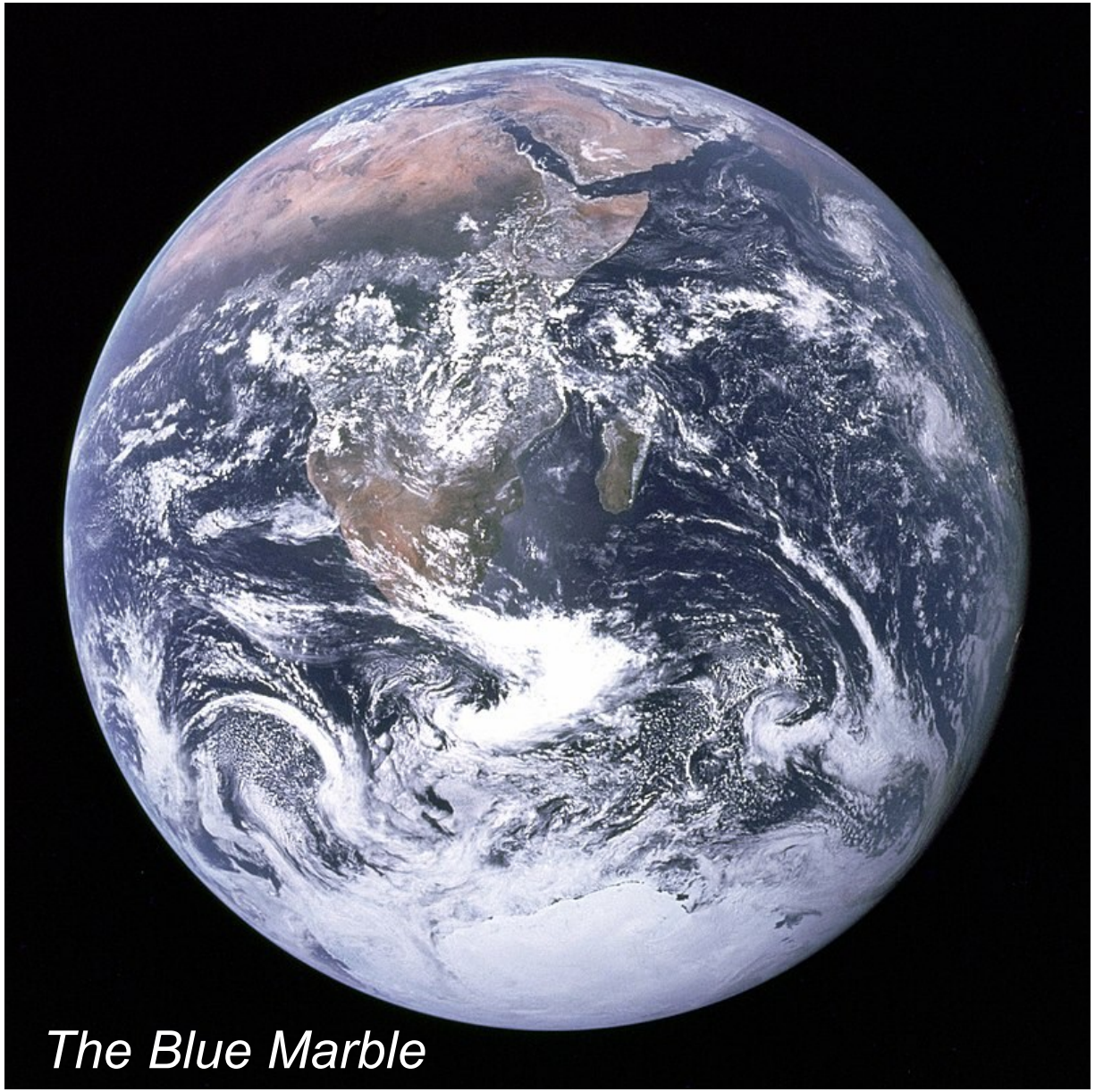


https://www.isac.cnr.it/dinamica/davolio/tmp/Didattica/15-Circolazione.pdf

https://www.giss.nasa.gov/research/briefs/2017_tselioudis_02/

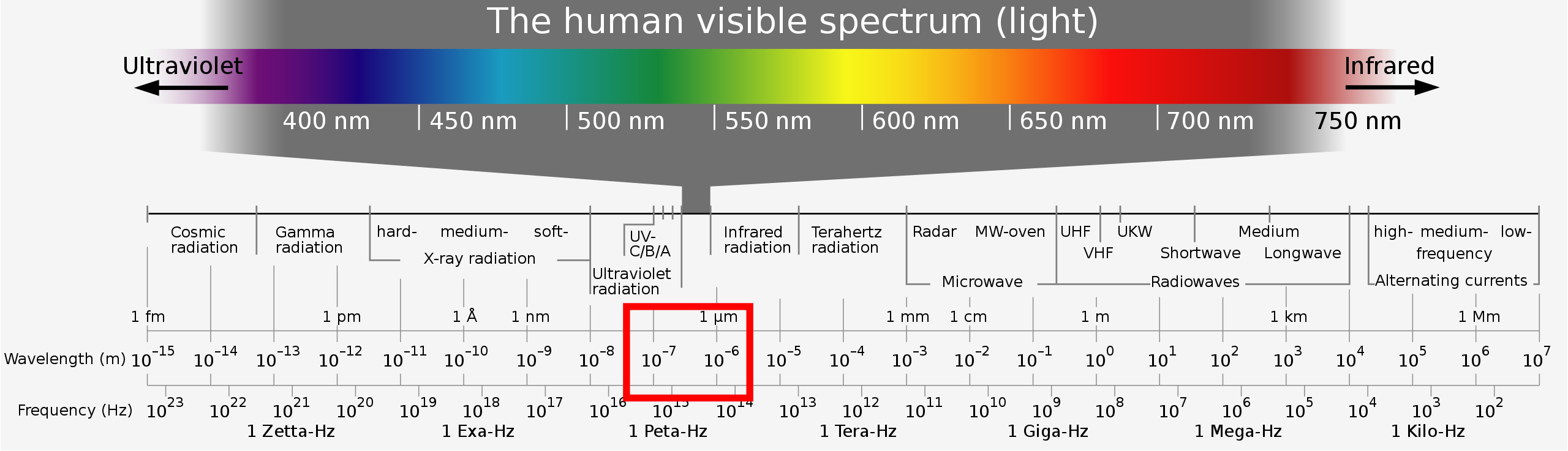
Circolazione generale degli oceani

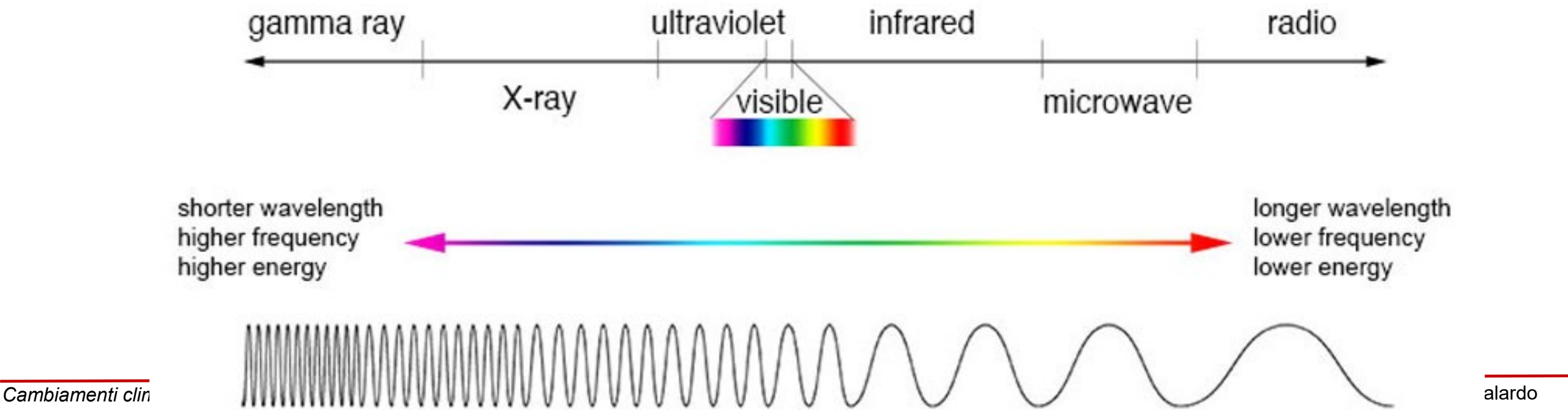




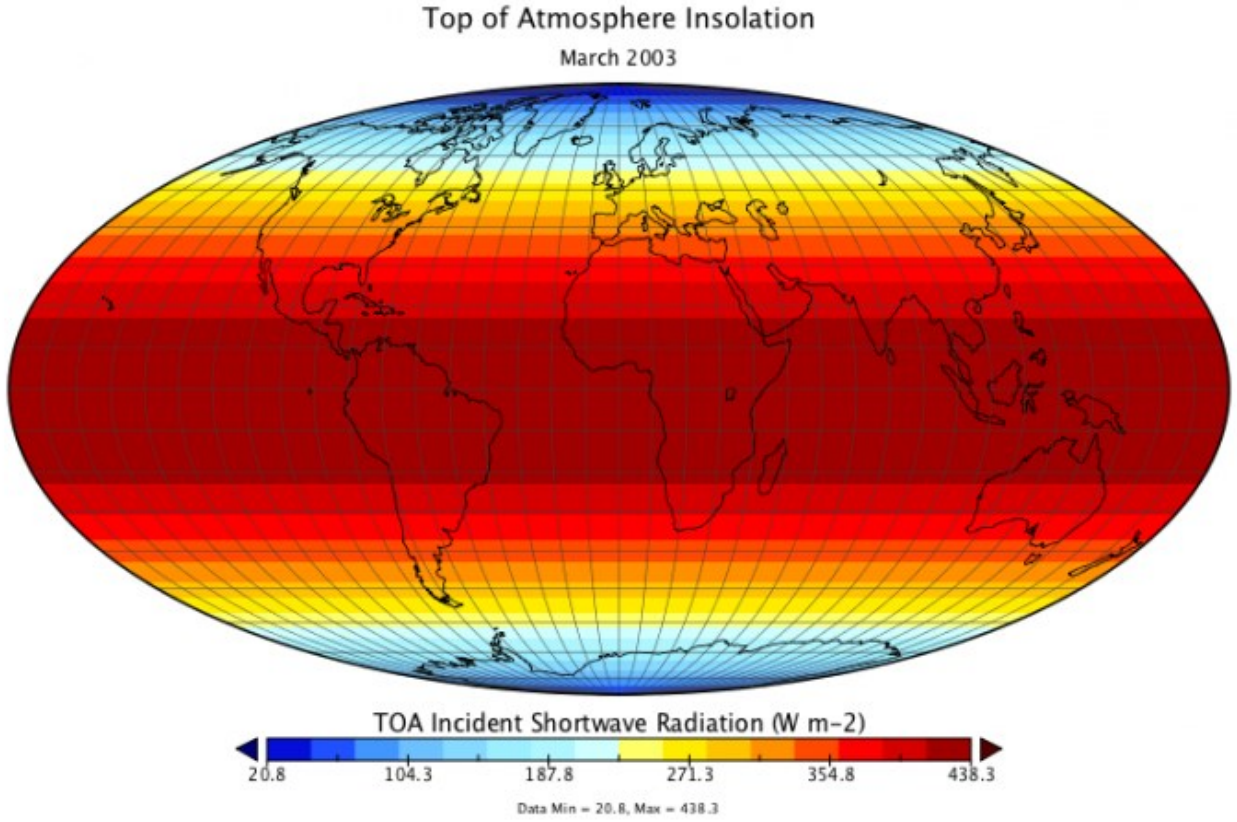
Variabilità del clima terrestre

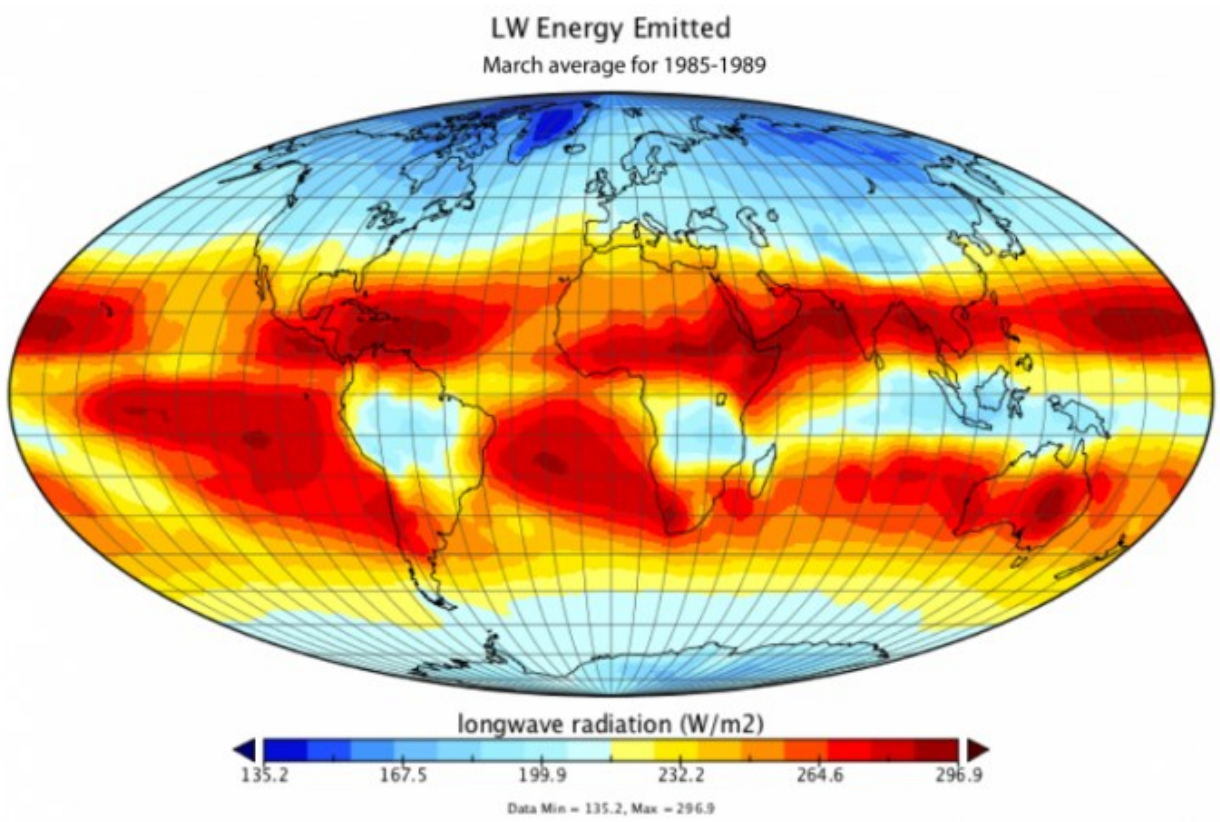
- La Terra possiede un inviluppo fluido che la circonda (atmosfera + oceano).
- Atmosfera e oceano permettono una **ridistribuzione** efficace del calore (attraverso i venti e la circolazione atmosferica, e le correnti oceaniche) dalle regioni dove c'è un accumulo di calore (basse latitudini) a quelle dove c'è un deficit (alte latitudini)
- Condizioni prossime al punto triplo dell'acqua
- L'acqua (nelle diverse forme) circola attraverso il sistema generale dando luogo al ciclo idrologico, che influenza ed è influenzato dal clima stesso


The human visible spectrum (light)
Ultraviolet
Infrared
400 nm
450 nm
500 nm
550 nm
600 nm
650 nm
700 nm
750 nm
Cosmic radiation
Gamma radiation
hard-
medium-
soft-
X-ray radiation
UV-C/B/A
Ultraviolet radiation
Infrared radiation
Terahertz radiation
Radar
MW-oven
Microwave
UHF
UKW
VHF
Shortwave
Medium
Longwave
Radiowaves
high-
medium-
low-
frequency
Alternating currents
1 fm
1 pm
1 Å
1 nm
1 µm
1 mm
1 cm
1 m
1 km
1 Mm
Wavelength (m)
Frequency (Hz)
1 Zetta-Hz
1 Exa-Hz
1 Peta-Hz
1 Tera-Hz
1 Giga-Hz
1 Mega-Hz
1 Kilo-Hz


gamma ray
ultraviolet
infrared
radio
X-ray
visible
microwave
shorter wavelength
higher frequency
higher energy
longer wavelength
lower frequency
lower energy

Variabilità del clima: energia termica e trasporto di calore

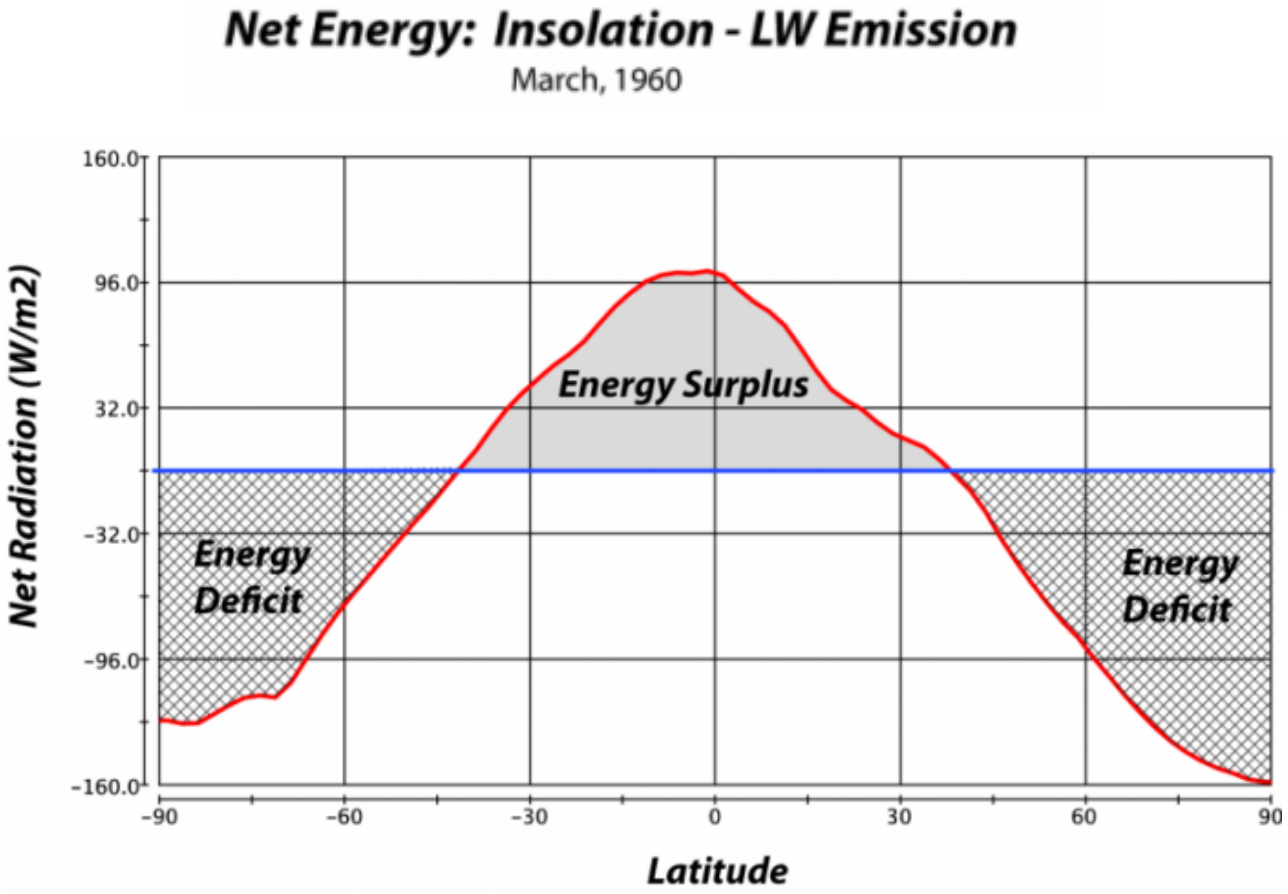


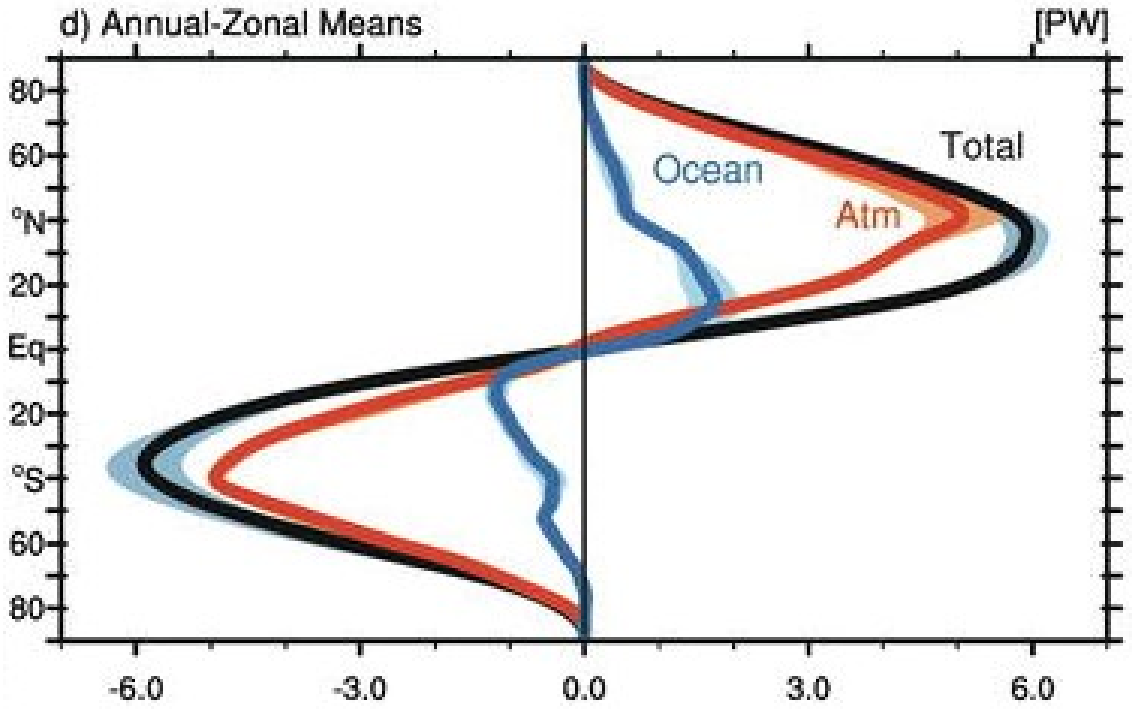


L'energia termica viene ridistribuita dalle basse alle alte latitudini grazie ai processi di trasporto nell'atmosfera (venti) e nell'oceano (correnti

https://www.e-education.psu.edu/earth103/node/1007

Il motore del sistema climatico: bilancio e flussi di calore





The median annual mean transport by latitude for the total (gray), atmosphere (red), and ocean (blue) accompanied with the associated range (shaded).

The insolation reaching the surface averaged over March 1960, from NASA's ERBE experiment.
Credit: David Bice Penn State University is licensed under CC BY-NC-SA 4.0

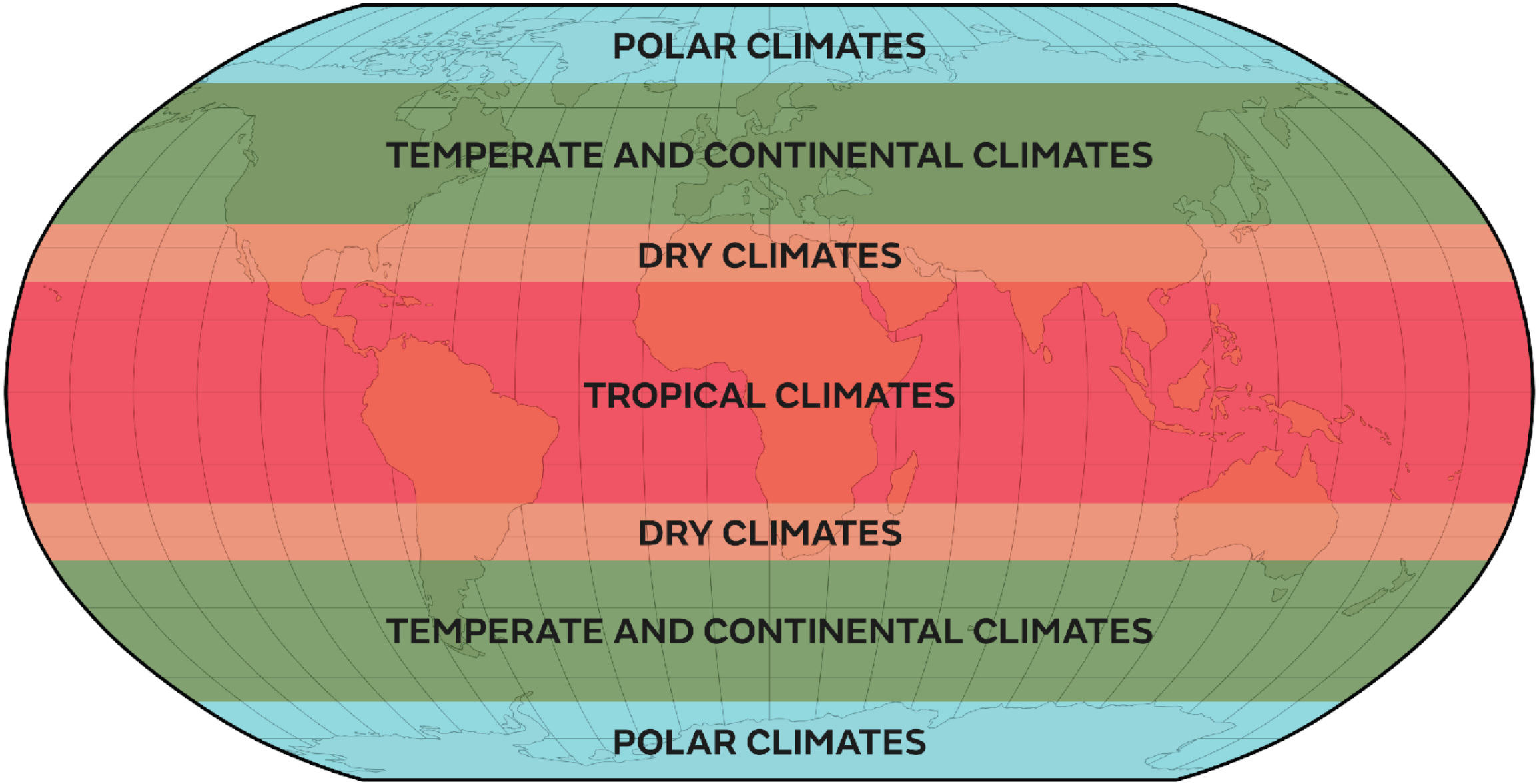
in brief: il clima terrestre è…

… il risultato dell'interazione di molti fattori e processi:

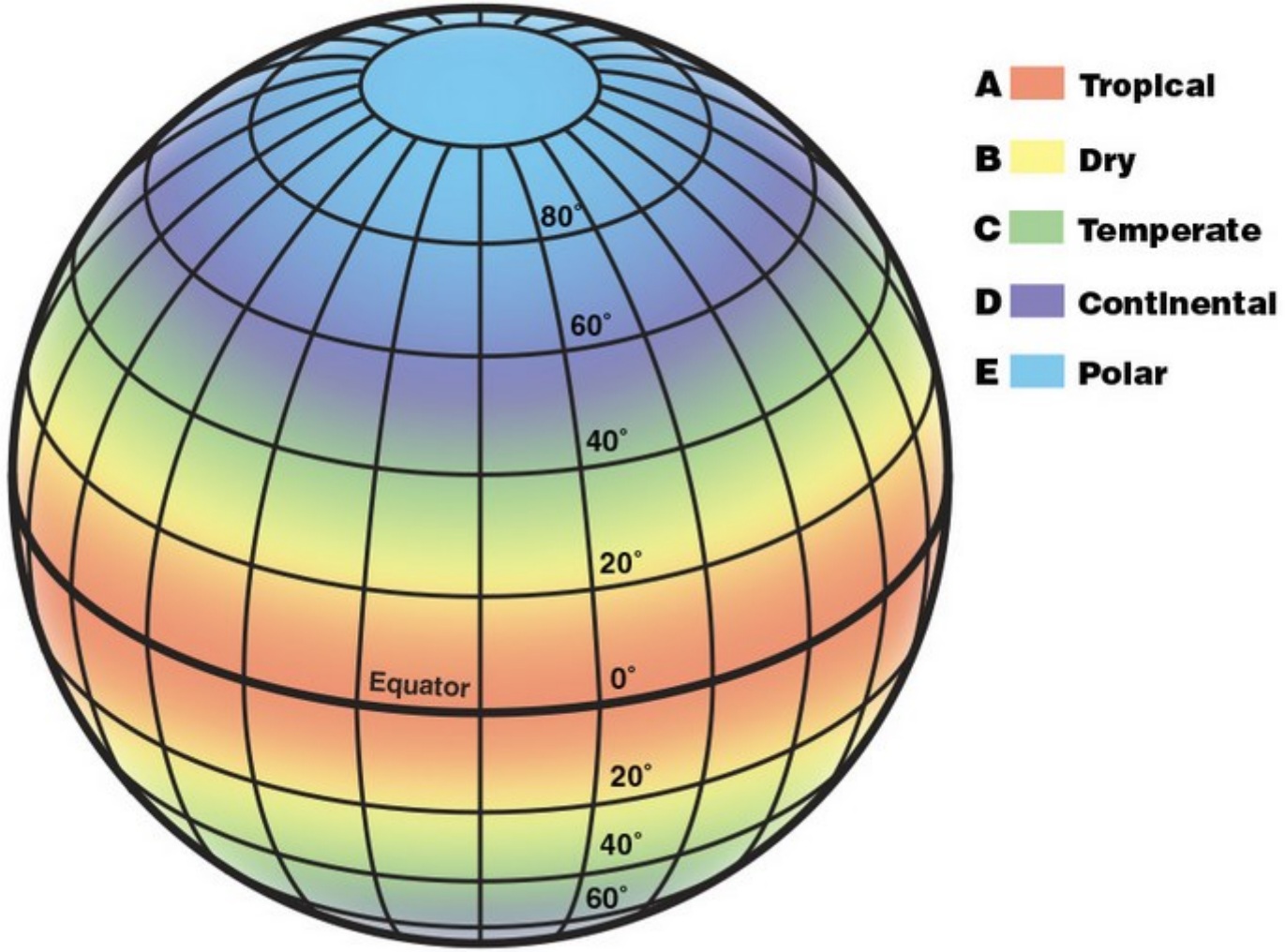
- Radiazione solare e geometria orbitale (latitudine e stagionalità)
- Circolazione atmosferica (costituenti e ciclo idrologico)
- Circolazione oceanica (costituenti e ciclo idrogeologico)
- Geografia delle terre emerse/oceani (distribuzione, ghiacciai, orografia)
- Ciclo idrogeologico, interazioni biosfera/atmosfera, geochimica della superficie terrestre

Sistemi di classificazione del clima

Met Office



https://www.metoffice.gov.uk/weather/climate/climate-explained/climate-zones

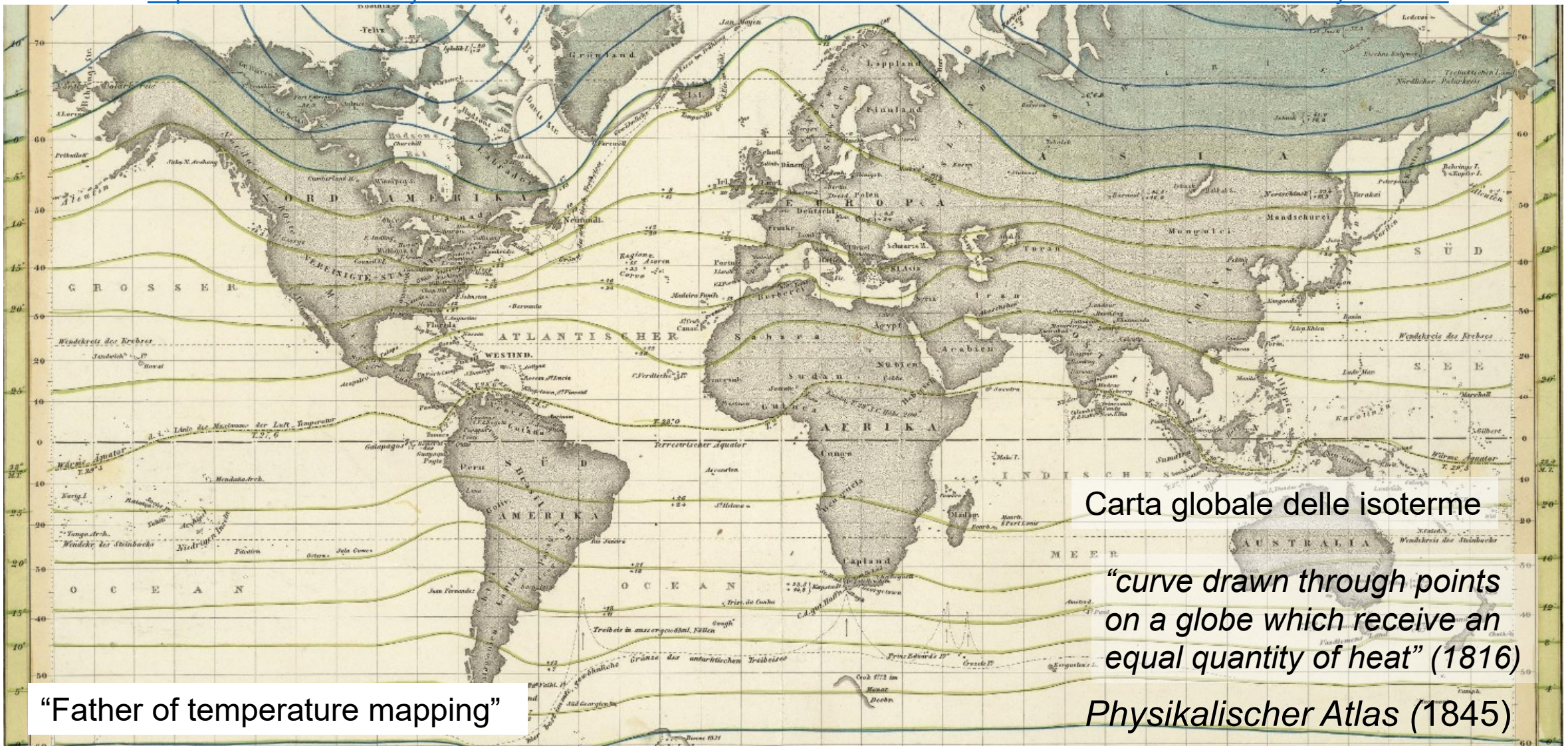


https://scijinks.gov/climate-zones/

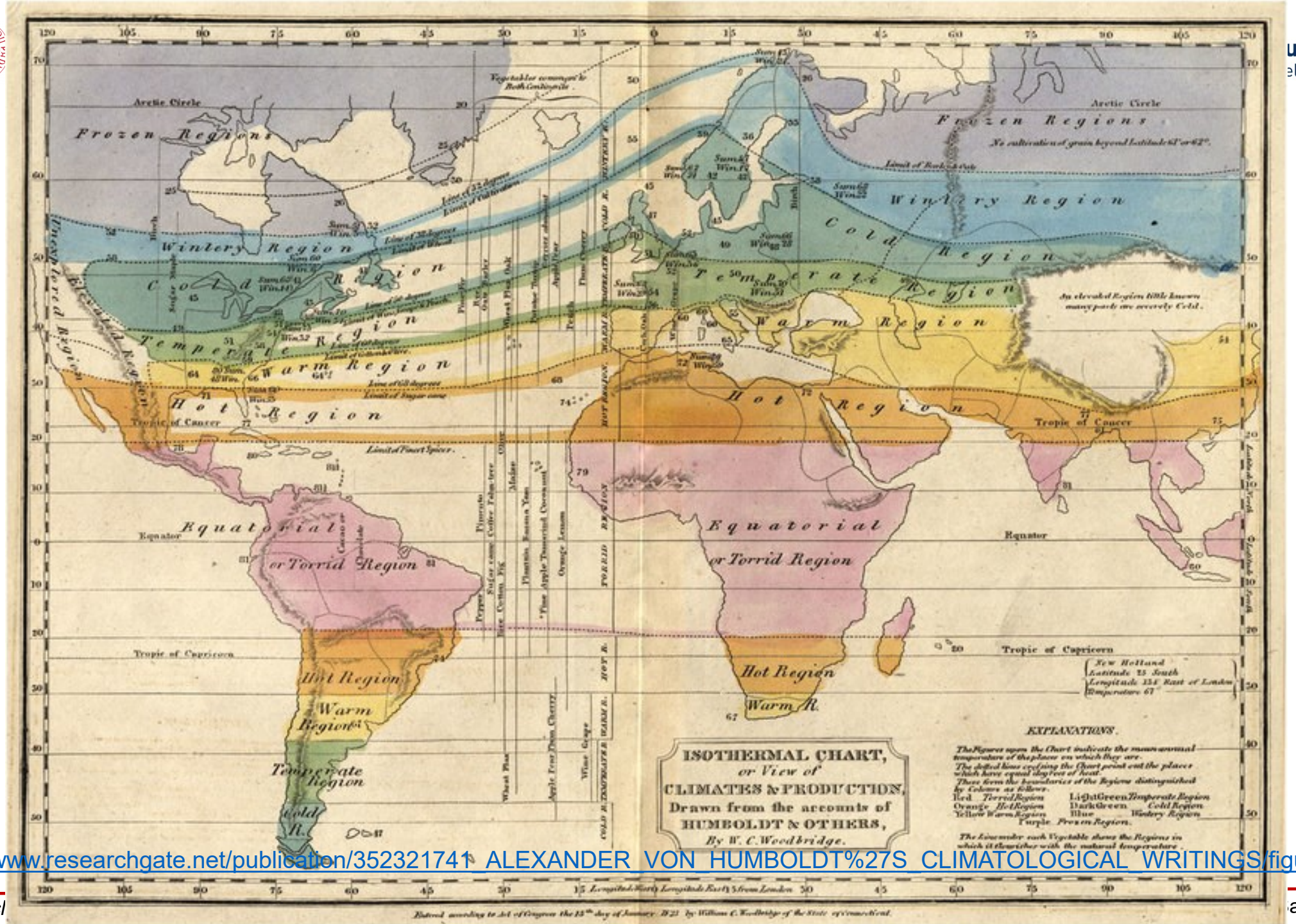
Sistemi di classificazione del clima

Radiazione netta
Temperatura (isoterme)
Precipitazione
Bilancio idrico
Vegetazione
Il sistema di Koppen

https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~1477~160017:Alexander-von-Humboldt-s-System-Der



Alexander von Humboldt (1769-1859)

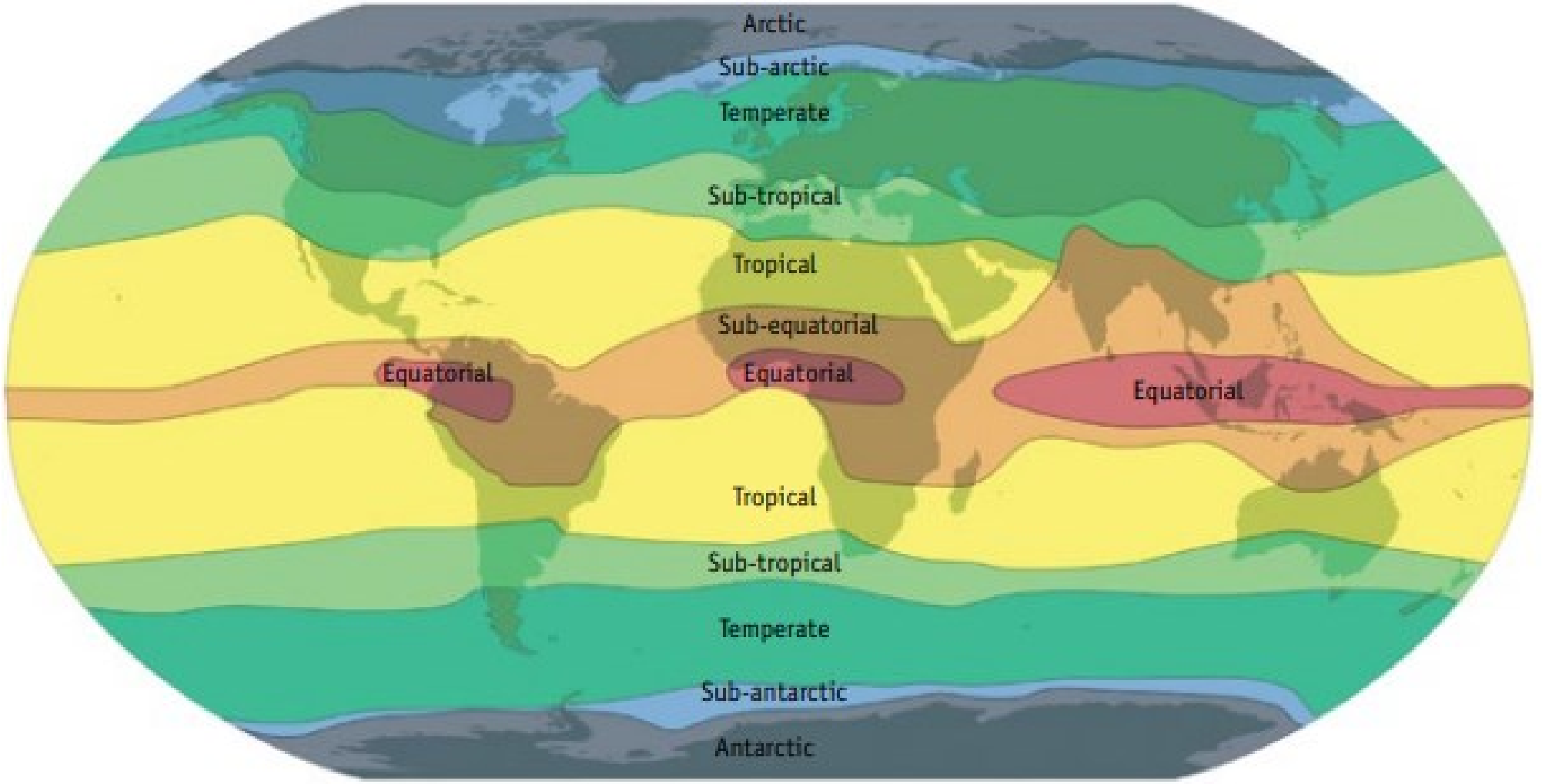


https://www.researchgate.net/publication/352321741_ALEXANDER_VON_HUMBOLDT%27S_CLIMATOLOGICAL_WRITINGS/figures?lo=1

Il sistema di Koppen

- Base empirica
- Temperatura e precipitazione (medie annue e mensili) (e umidità)
- Stazioni meteorologiche
- Non si tiene conto delle cause (pressione, fasce dei venti, fronti o perturbazioni)

Fig. 1.2.1. The Earth's climates (by B. Alisov).



https://climate-box.com/textbooks/the-problem-of-climate-change/2-2-effects-on-plants-and-animals/

Sistema di classificazione climatica Köppen

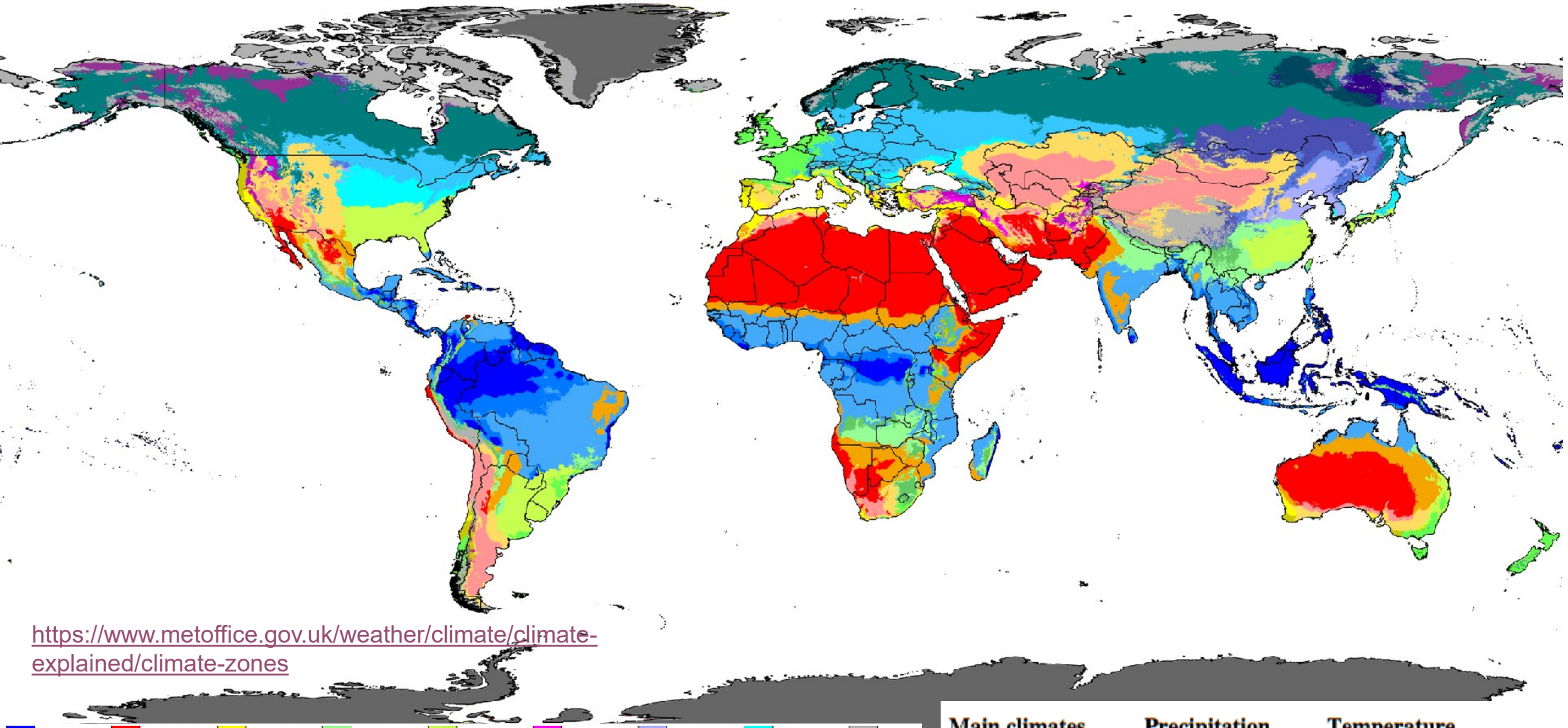
- Primo schema nel 1918
- Modificato e aggiornato

- Sistema numerico di classificazione basato **su valori annui di T e precipitazione**, combinati tra loro
- Consente di cartografare la distribuzione geografica di qualsiasi tipologia climatica (locale e globale)

Sistema Köppen modificato

- 4 gruppi climatici (A, B, C, D, E)
- 1 categoria speciale clima di altitudine (H)
- 15 climi individuali

Main climates	Precipitation	Temperature	
A: equatorial	W: desert	h: hot arid	F: polar frost
B: arid	S: steppe	k: cold arid	T: polar tundra
C: warm temperate	f: fully humid	a: hot summer	
D: snow	s: summer dry	b: warm summer	
E: polar	w: winter dry	c: cool summer	
	m: monsoonal	d: extremely continental	



https://www.metoffice.gov.uk/weather/climate/climate-explained/climate-zones

Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh	Csc	Cwc	Cfc	Dsc	Dwc	Dfc	
	BSk				Dsd	Dwd	Dfd	

Main climates	Precipitation	Temperature	
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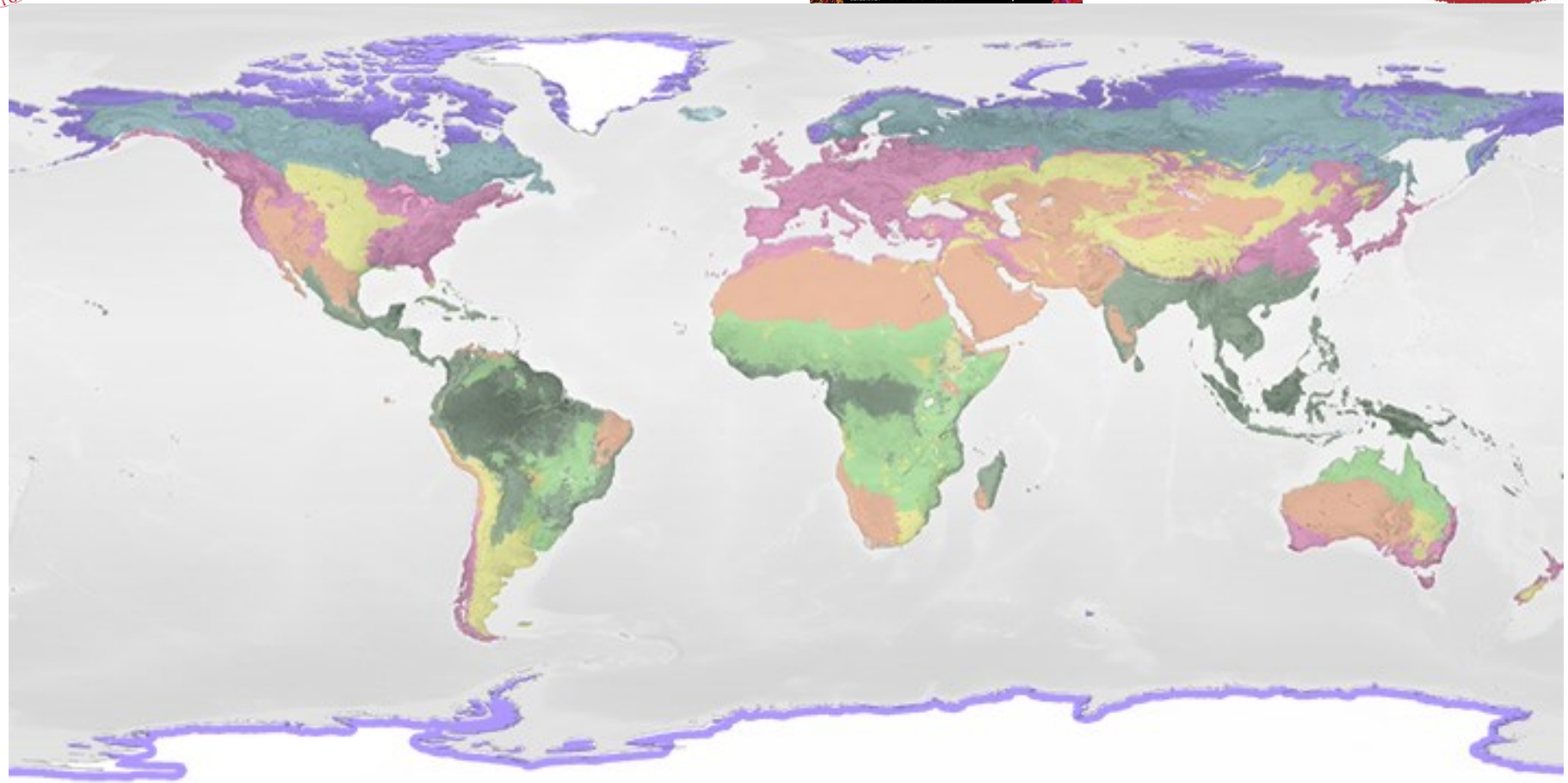


Click on a biome button below for more information on that biome (download image).

Rainforest | Grassland | Coniferous Forest | Temperate Deciduous Forest | Desert | Tundra | Shrubland

https://earthobservatory.nasa.gov/biome

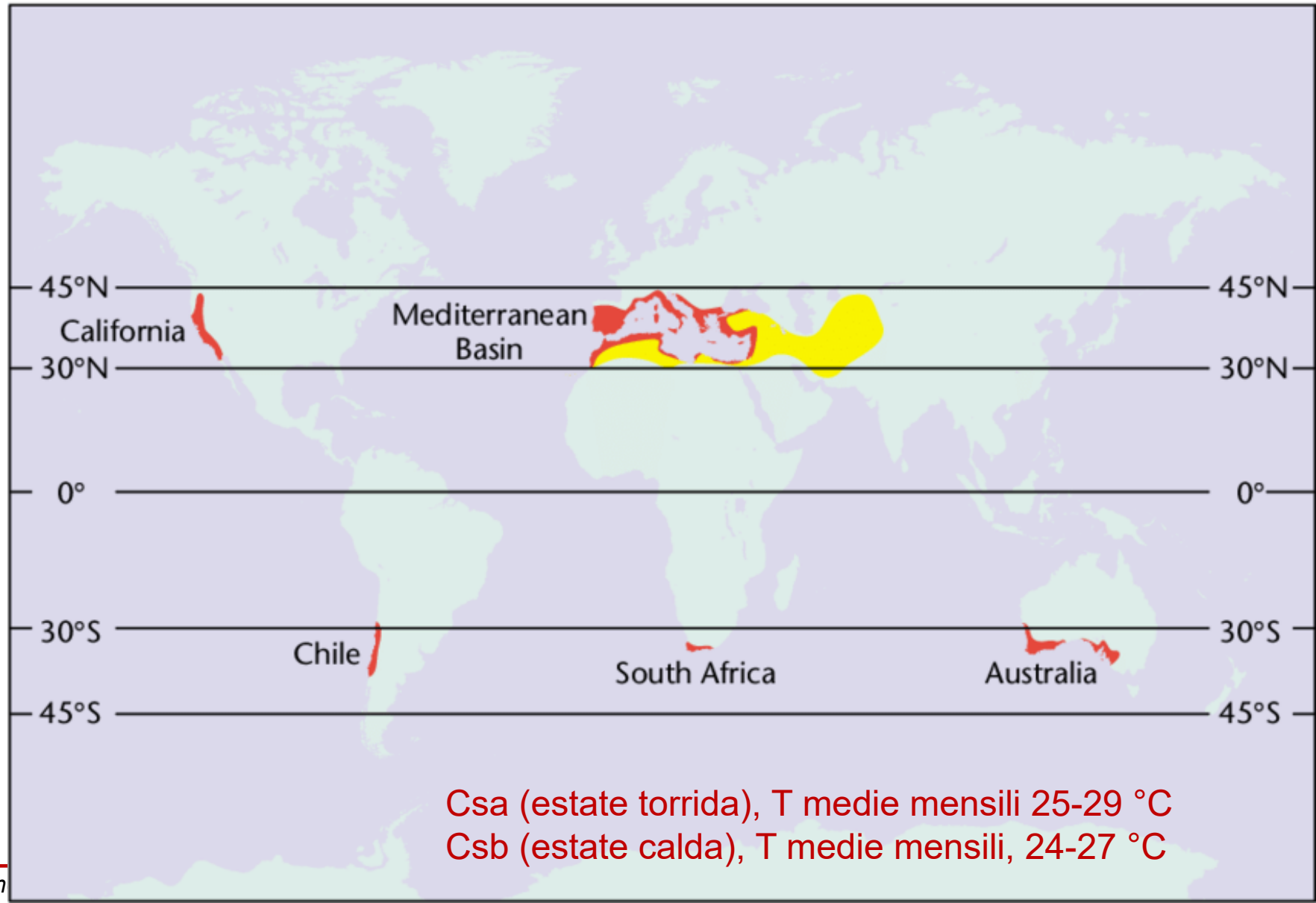
Sistema di classificazione climatica Köppen: i climi mediterranei

Climi temperati medie latitudini (Cs)

Climi subtropicali a estate asciutta

- Precipitazione annua limitata
- T invernale mite
- Estati calde (o torride)
- Estati con cielo sereno, Insolazione elevata

- Precipitazione media 350-900 mm/annui
- 2-3 mesi estivi poco piovosi

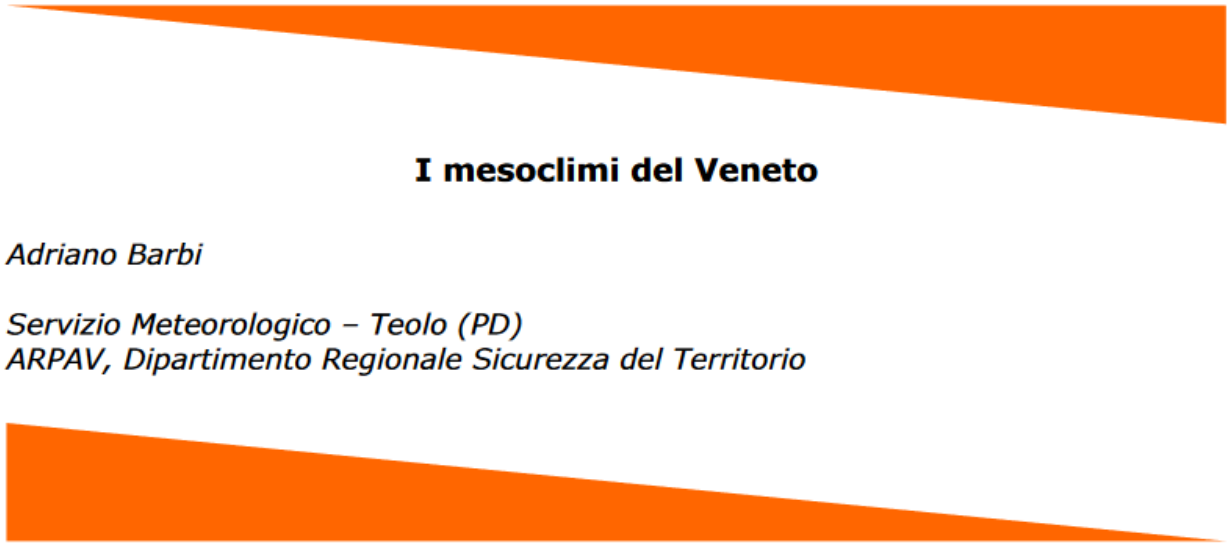


Csa (estate torrida), T medie mensili 25-29 °C
Csb (estate calda), T medie mensili, 24-27 °C

Il clima in Veneto

- Cfa
- Cfb
- Mesoclimi a macroscala
- Mesoclimi a mesoscala

il mesoclima della pianura
- il mesoclima prealpino
- il mesoclima alpino interno



https://www.arpa.veneto.it/arpavinforma/indicatori-ambientali/indicatori_ambientali/clima-e-rischi-naturali/clima

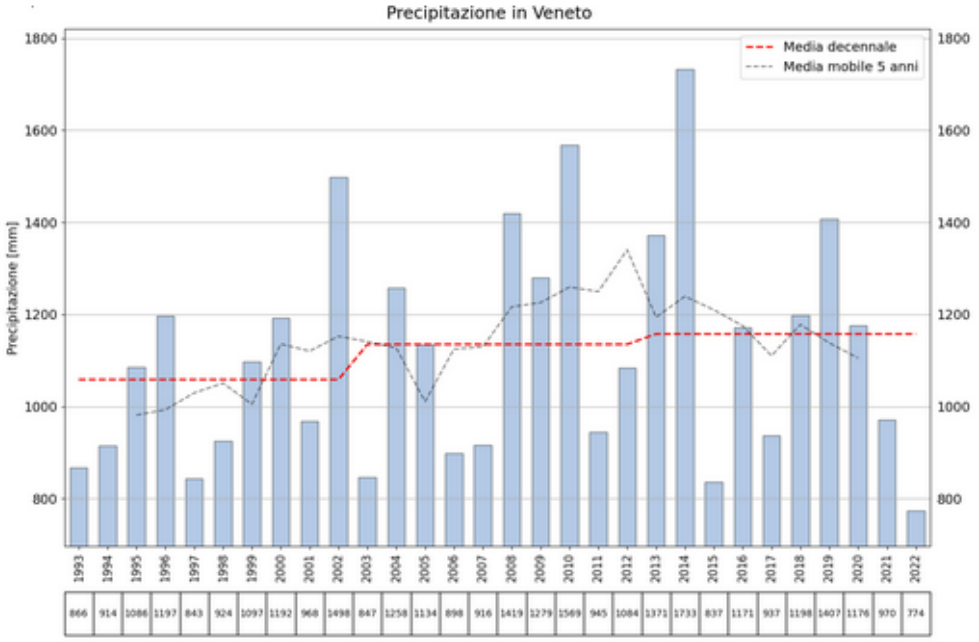
https://www.arpa.veneto.it/temi-ambientali/agrometeo/file-e-allegati/atlante/inquadramento-climatico-del-veneto.pdf/@@display-file/file

https://www.arpa.veneto.it/servizi-ambientali/comunicazione/parliamo-di../cambiamenti-climatici

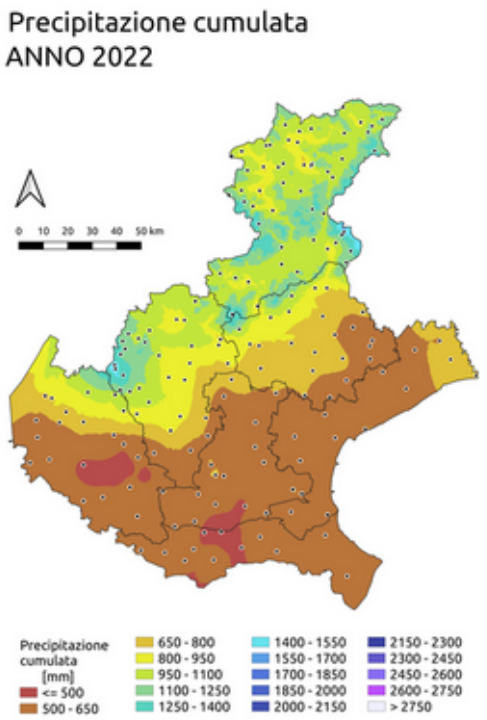
https://www.arpa.veneto.it/arpavinforma/indicatori-ambientali/indicatori_ambientali/clima-e-rischi-naturali/clima

Valutazione

Nel corso dell'anno 2022 si stima che mediamente siano caduti sulla regione Veneto 774 mm di precipitazione; la precipitazione media annuale, ri
al periodo 1993-2021, è di 1.128 mm (mediana 1.091 mm): gli apporti meteorici annuali sul territorio regionale sono stati stimati in circa 14.248 milioni di m3 di acqua e **risultano inferiori alla media del 31%.**



Precipitazioni annuali nel periodo 1993-2022
(medie calcolate sull'intero territorio regionale)

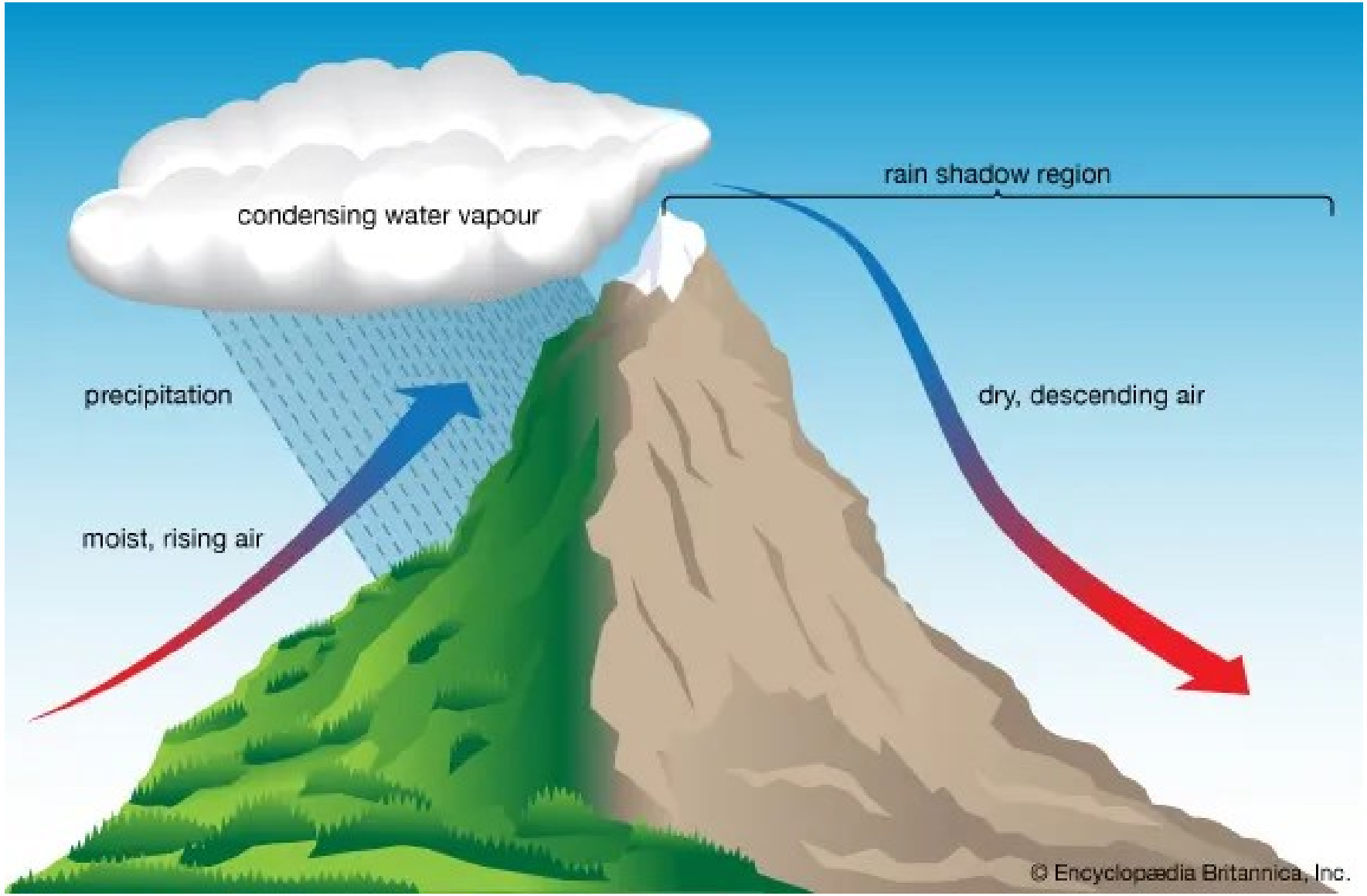


Precipitazioni in mm nel 2022 in Veneto

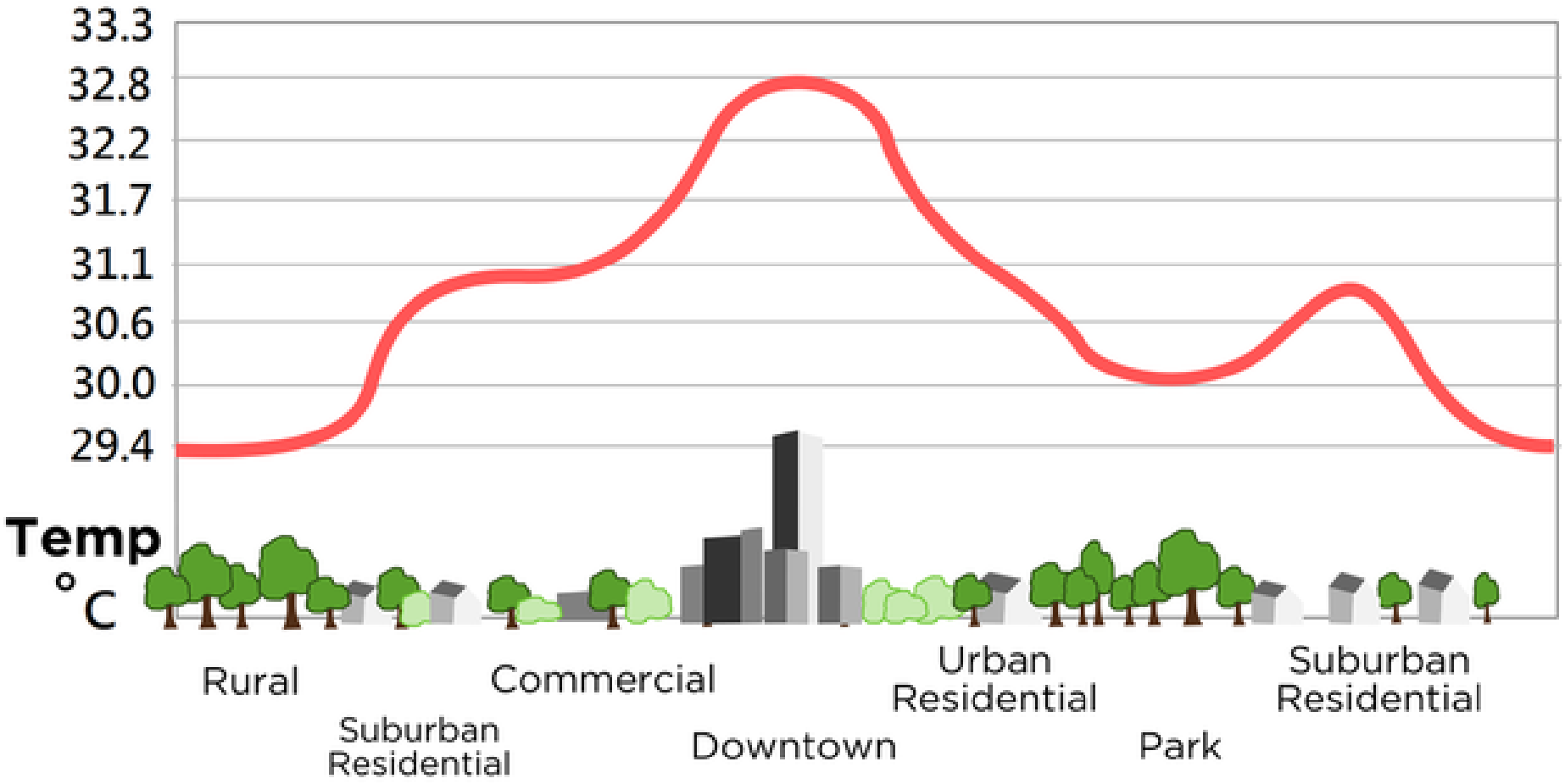
What is a microclimate?

A microclimate is a small area with a different climate to its surroundings.
This could be due to **nearby landmarks, such as lakes or hills**, affecting wind patterns or sheltering the area from the sun.
They can also be produced by artificial structures such as buildings.
The size of a microclimate can vary as it is simply defined as having a different climate to its surroundings.
It could be **as small as a few square metres**, such as a shaded corner of a garden which certain plants will prefer. **It could be larger,** such as a sheltered woodland dell or an isolated mountain peak.
Many cities have their own microclimate or many microclimates, as buildings and artificial surfaces absorb heat during the day and create an Urban Heat Island, as well as altering wind flows.

https://www.metoffice.gov.uk/weather/climate/climate-explained/climate-zones


condensing water vapour
rain shadow region
precipitation
dry, descending air
moist, rising air
© Encyclopædia Britannica, Inc.

URBAN HEAT ISLAND PROFILE



http://geographylaunchpad.weebly.com/urban-microclimates.html

Forzanti antropogeniche sul sistema climatico:

- Aumento frequenza eventi meteo estremi (siccità, HWs, nubifragi)
- Zone climatiche
- Stagionalità

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Amanda Leigh Mascarelli

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https://www.nature.com/articles/nature.2013.12838

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Myron King, Daniel Altdorff, Pengfei Li, Lakshman Galagedara, Joseph Holden & Adrian Unc

Scientific Reports **8**, Article number: 7904 (2018) | Cite this article

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https://www.nature.com/articles/s41598-018-26321-8

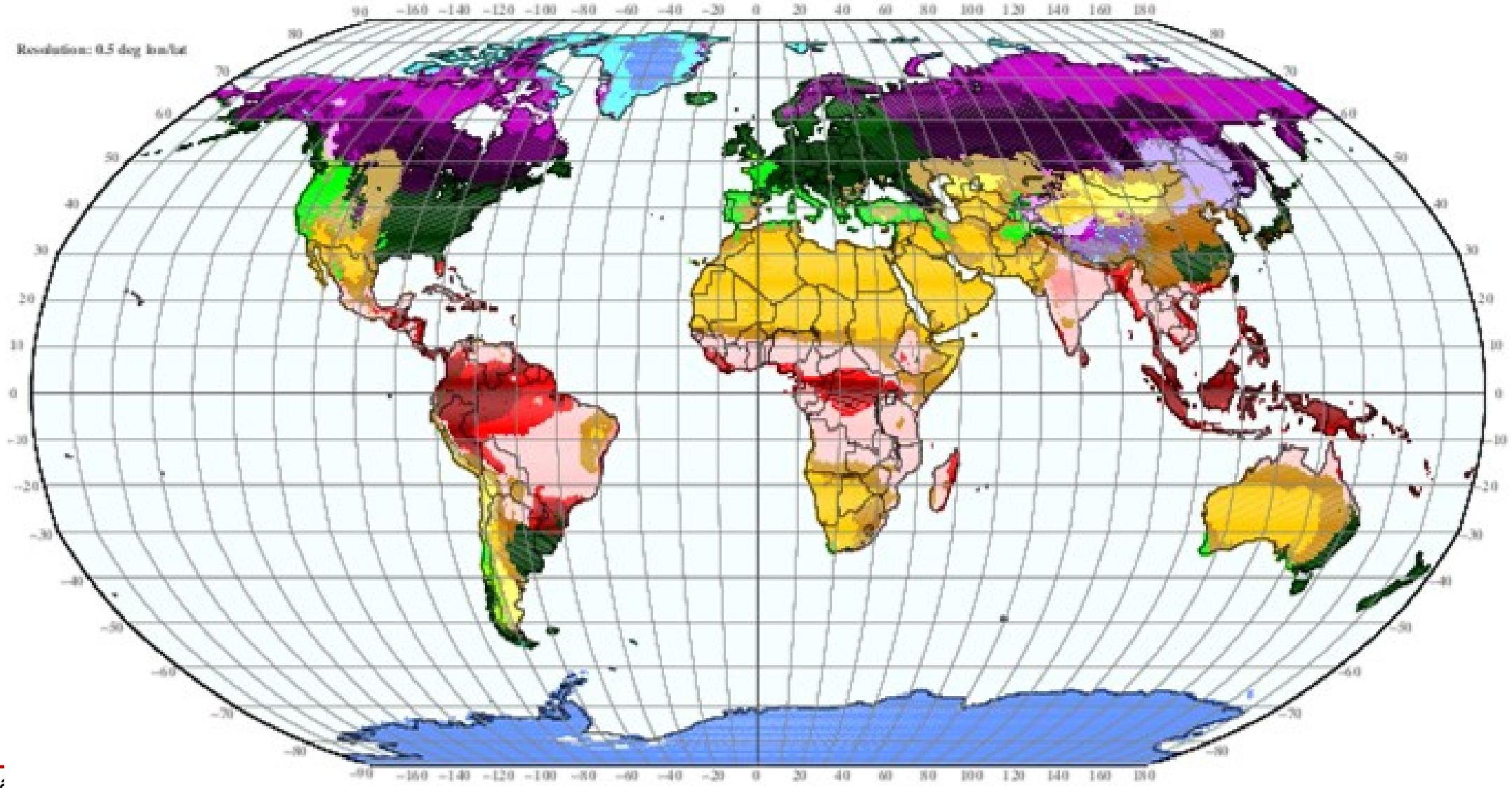
World Map of Köppen–Geiger Climate Classification

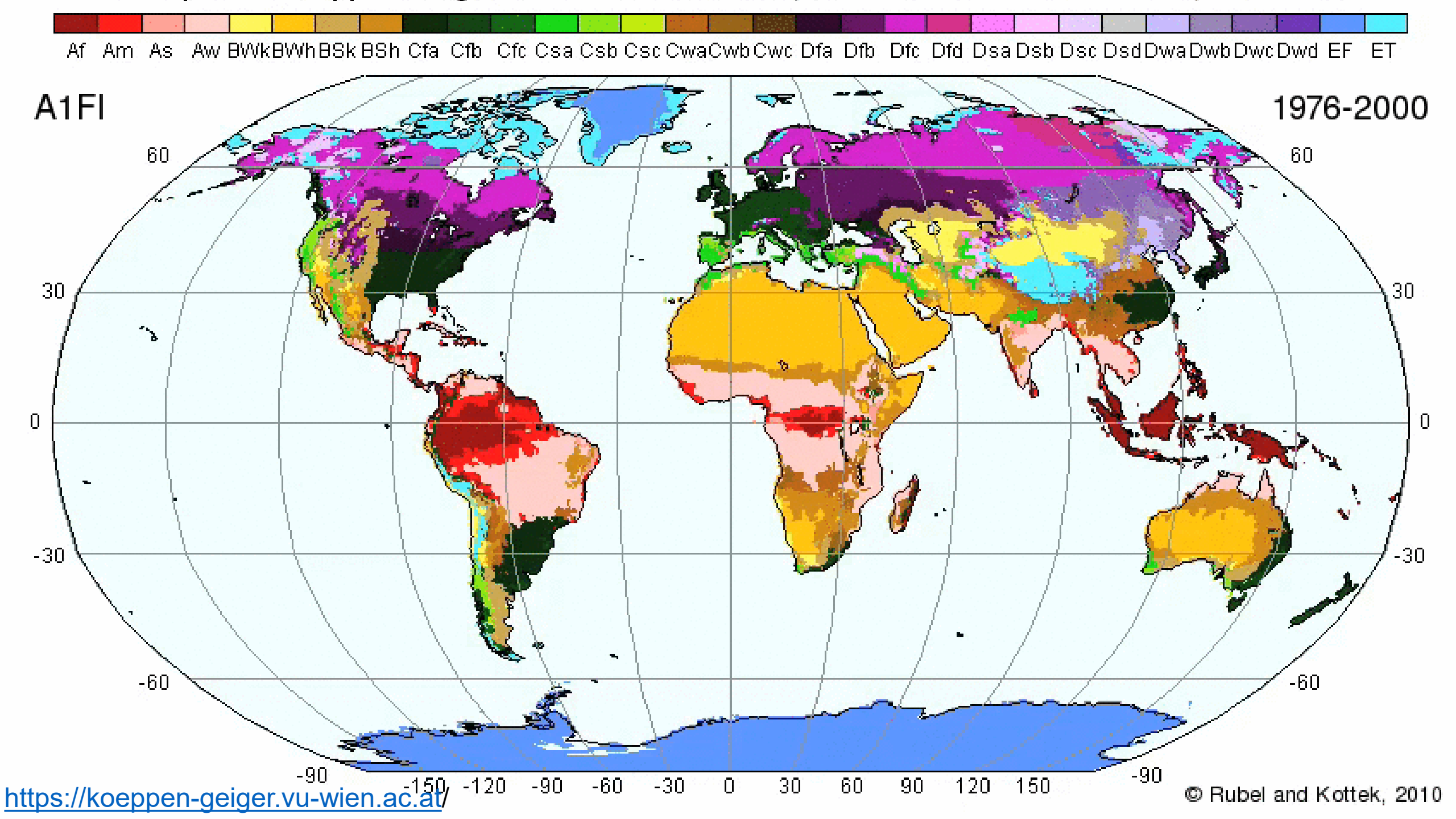
projected using IPCC A1FI Tyndall SC 2.03temperature and precipitation scenarios, period 2076 - 2100

Main climates	Precipitation	Temperature	
A: equatorial	W: desert	h: hot arid	F: polar frost
B: arid	S: steppe	k: cold arid	T: polar tundra
C: warm temperate	f: fully humid	a: hot summer	
D: snow	s: summer dry	b: warm summer	
E: polar	w: winter dry	c: cool summer	
	m: monsoonal	d: extremely continental	

Af Am As Aw BWk BWh BSk BSh Cfa Cfb Cfc Csa Csb Csc Cwa

Cwb Cwc Dfa Dfb Dfc Dfd Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd EF ET





https://koeppen-geiger.vu-wien.ac.at/

Sistema di classificazione climatica Köppen

https://www.metoffice.gov.uk/weather/climate/climate-explained/climate-zones

Main climates	Precipitation	Temperature	
A: equatorial	W: desert	h: hot arid	F: polar frost
B: arid	S: steppe	k: cold arid	T: polar tundra
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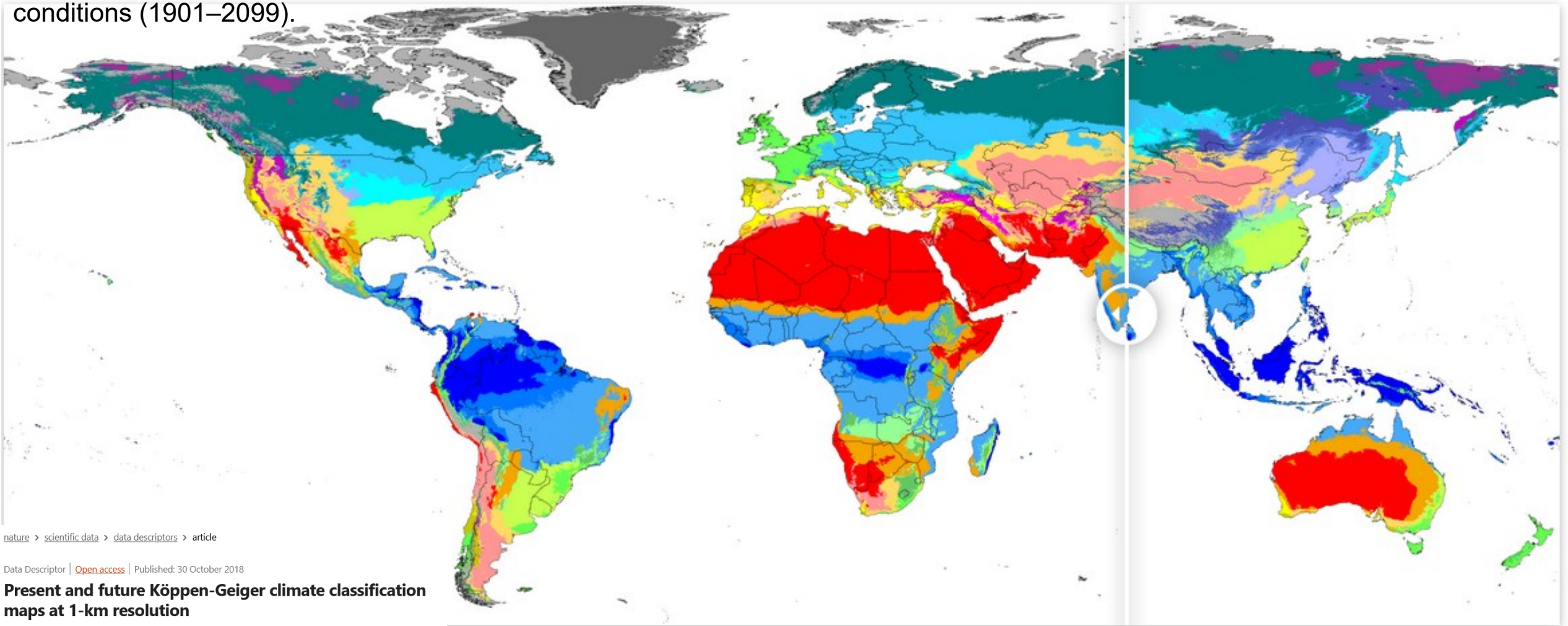
We present new global maps of the Köppen-Geiger climate classification at a high 1-km resolution for historical and future climate conditions (1901–2099).



nature › scientific data › data descriptors › article

Data Descriptor | Open access | Published: 30 October 2018

Present and future Köppen-Geiger climate classification maps at 1-km resolution

Hylke E. Beck, Niklaus E. Zimmermann, Tim R. McVicar, Noemi Vergopolan, Alexis Berg & Eric F. Wood

Scientific Data 5, Article number: 180214 (2018) | Cite this article

242k Accesses | 2932 Citations | 285 Altmetric | Metrics

A Publisher Correction to this article was published on 17 August 2020

Af Am Aw BWh BWk BSh BSk Csa Csb Csc Cwa Cwb Cwc Cfa Cfb Cfc Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd Dfa Dfb Dfc Dfd ET EF

https://www.gloh2o.org/koppen/
https://www.nature.com/articles/sdata201821

Non ci sono più le mezze stagioni?

#DailyStripe

Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL091753

Changing Lengths of the Four Seasons by Global Warming

Jiamin Wang[1,2], Yuping Guan[2], Lixin Wu[3,4], Xiaodan Guan[1], Wenju Cai[3,4,5], Jianping Huang[1], Wenjie Dong[6,7], and Banglin Zhang[8]

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Jiamin Wang and Yuping Guan contributed equally to this work.

Key Points:

- Climate change has driven longer and hotter summers, shorter and warmer winters, shorter springs and autumns
- The onsets of spring and summer are advanced, while the onsets of autumn and winter are delayed
- Such changes in four seasons can be mainly attributed to greenhouse-warming, and will be amplified under the business-as-usual scenario

Supporting Information:

- Supporting Information S1
- Movie S1

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Citation:
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Abstract How long will the four seasons be by 2100? Increasing evidence suggests that the length of a single season or in regional scales has changed under global warming, but a hemispherical-scale response of the four seasons in the past and future remains unknown. We find that summer in the Northern Hemisphere midlatitudes has lengthened, whereas winter has shortened, owing to shifts in their onsets and withdrawals, accompanied by shorter spring and autumn. Such changes in lengths and onsets can be mainly attributed to greenhouse-warming. Even if the current warming rate does not accelerate, changes in seasons will still be exacerbated in the future. Under the business-as-usual scenario, summer is projected to last nearly half a year, but winter less than 2 months by 2100. The changing seasonal clock signifies disturbed agriculture seasons and rhythm of species activities, more frequent heat waves, storms and wildfires, amounting to increased risks to humanity.

Plain Language Summary A series of phenomena such as early flowering of plants and early migratory birds are suggesting that the traditional four seasons may have changed. We focus on how the four seasons changed during 1952–2011 and will change by the end of this century in the warming

Ipotesi:
GHG stiano influendo sui ritmi stagionali

Segnali?

Changes in season:

1) Contrazione e dilatazione delle stagioni
2) *Shift* dell'entrata delle stagioni (*onset*)

Geophysical Research Letters
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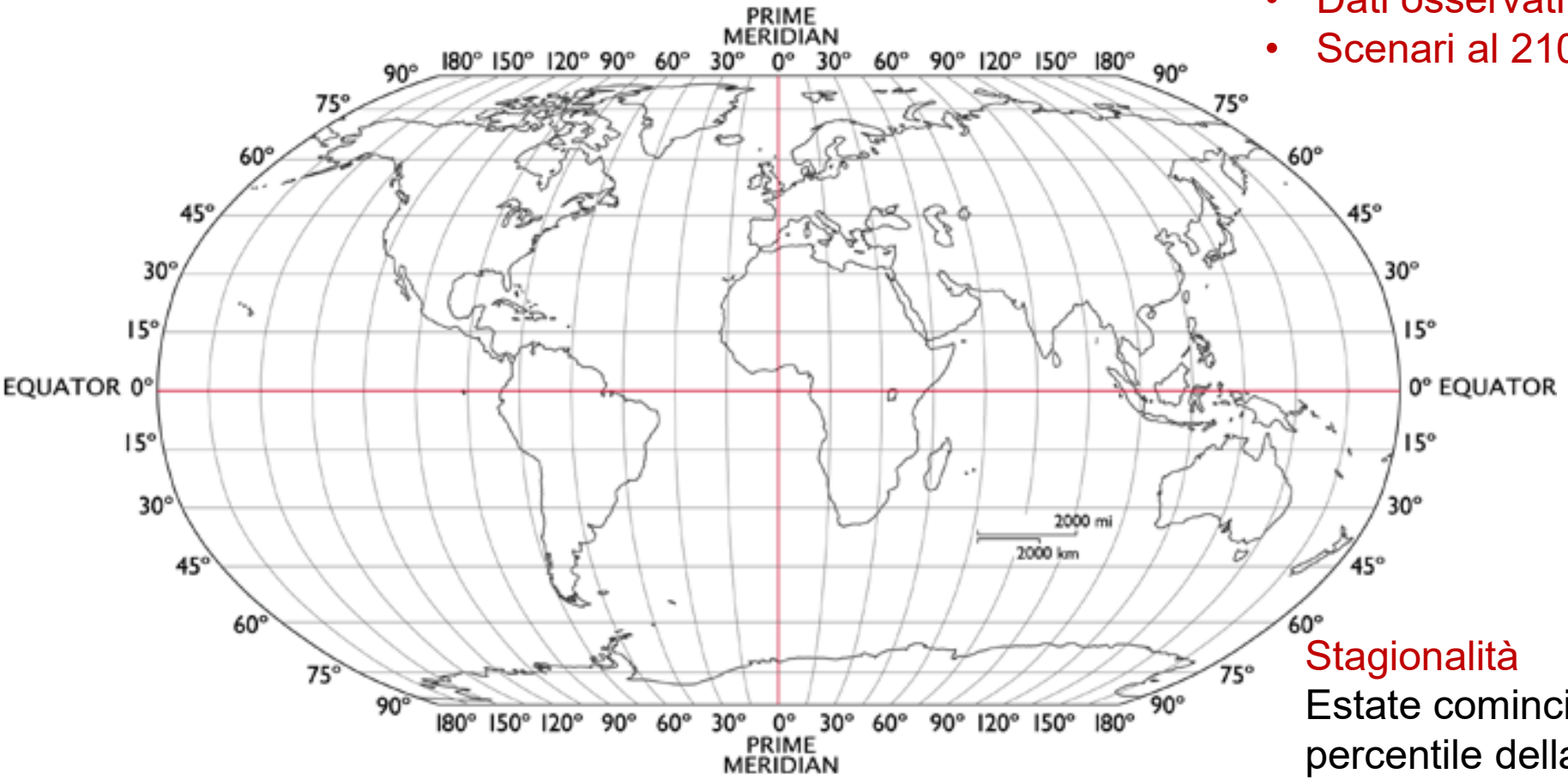
Changing Lengths of the Four Seasons by Global Warming

Come sono cambiate le quattro stagioni alle medie latitudini

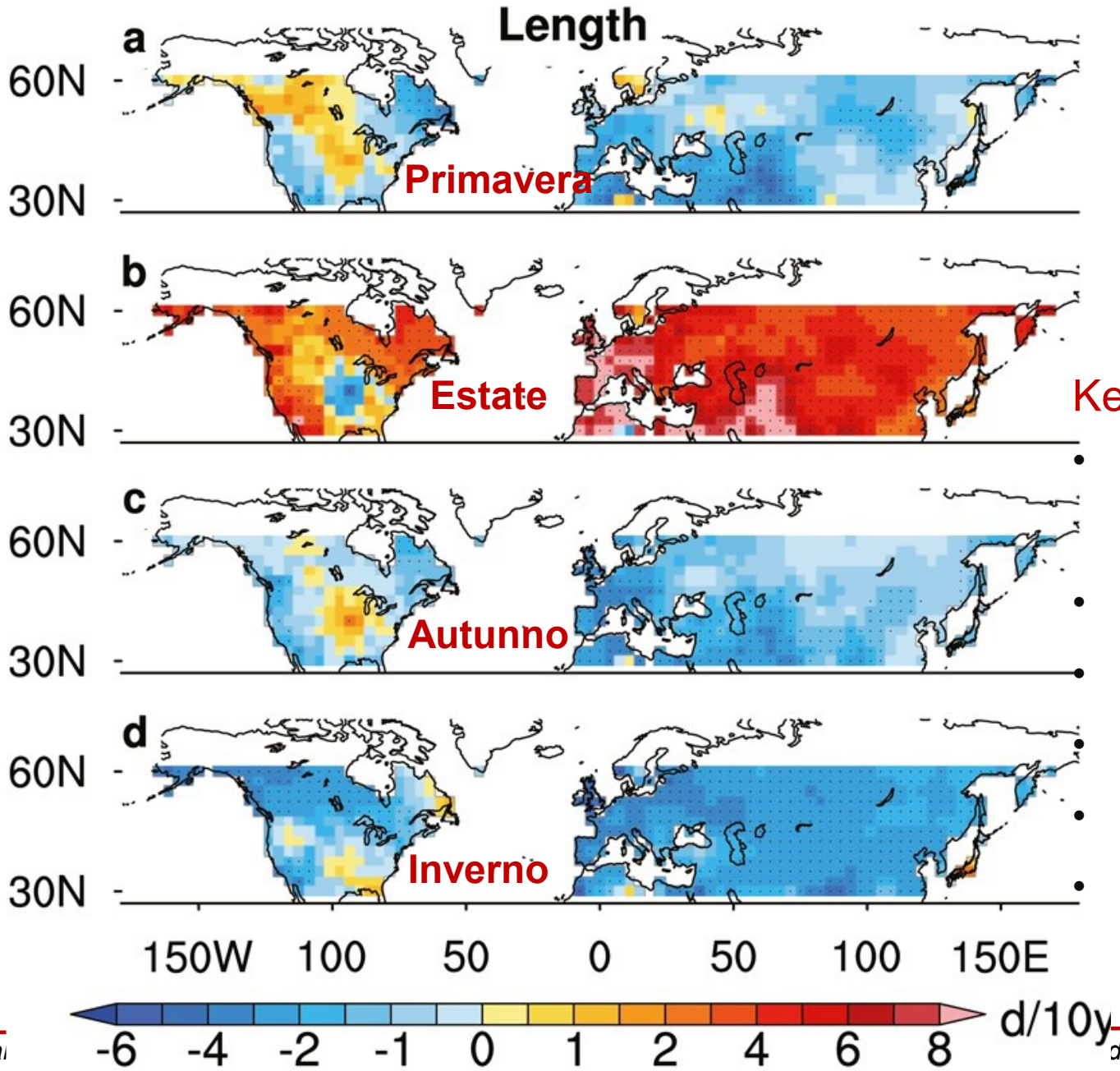
- Dati osservati e analisi multi-model 1951-2011
- Scenari al 2100 (*only multi-models*)

RCP 4.5 (+ SSP2-4.5)
RCP 8.5 (+ SSP2-8.5)



Stagionalità

Estate comincia quanto T supera il 75° percentile della T media 1951-2011
Inverno settato a T < 25° percentile
Primavera e autunno: incremento/decremento T



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Changing Lengths of the Four Seasons by Global Warming

Jiamin Wang and Yuping Guan contributed equally to this work.

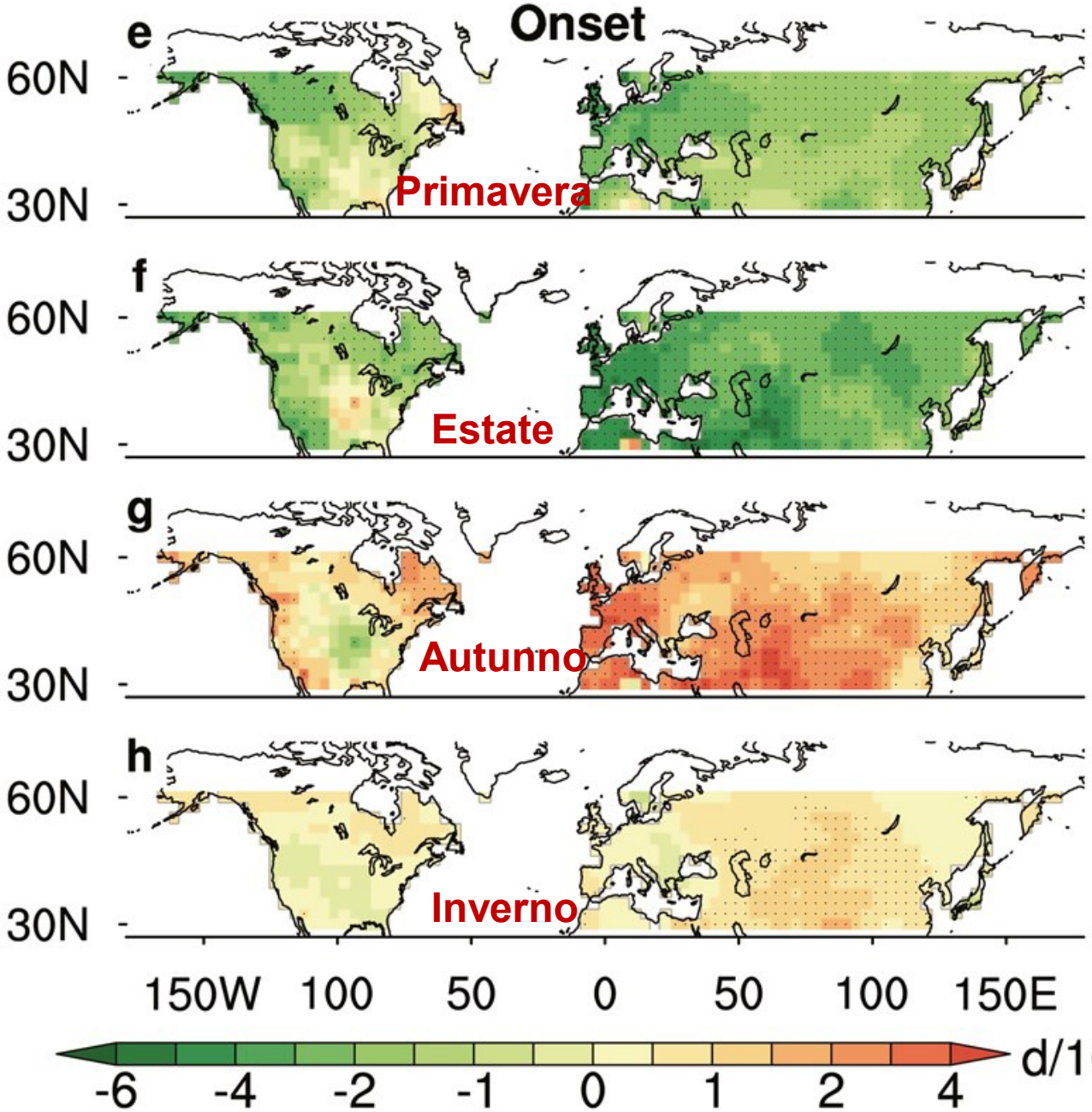
Jiamin Wang[1,2], Yuping Guan[2], Lixin Wu[3,4], Xiaodan Guan[1], Wenju Cai[3,4,5], Jianping Huang[1], Wenjie Dong[6,7], and Banglin Zhang[8]

[1]Key Laboratory for Semi-Arid Climate Change of the Ministry of Education, College of Atmospheric Sciences

Key Points:

Key findings **lunghezza** stagioni (periodo 1951-2011)

- A scala emisferica (nord) le estati si sono espanse (da 78 a 95 gg)
- Primavera, autunno e inverno si sono contratte
- Trend non omogenei: USA
- Rate medio aumento dell'estate 4.2 d/10y
- Rate medio diminuzione dell'inverno 2.1/10y
- Mediterraneo una delle aree più colpite

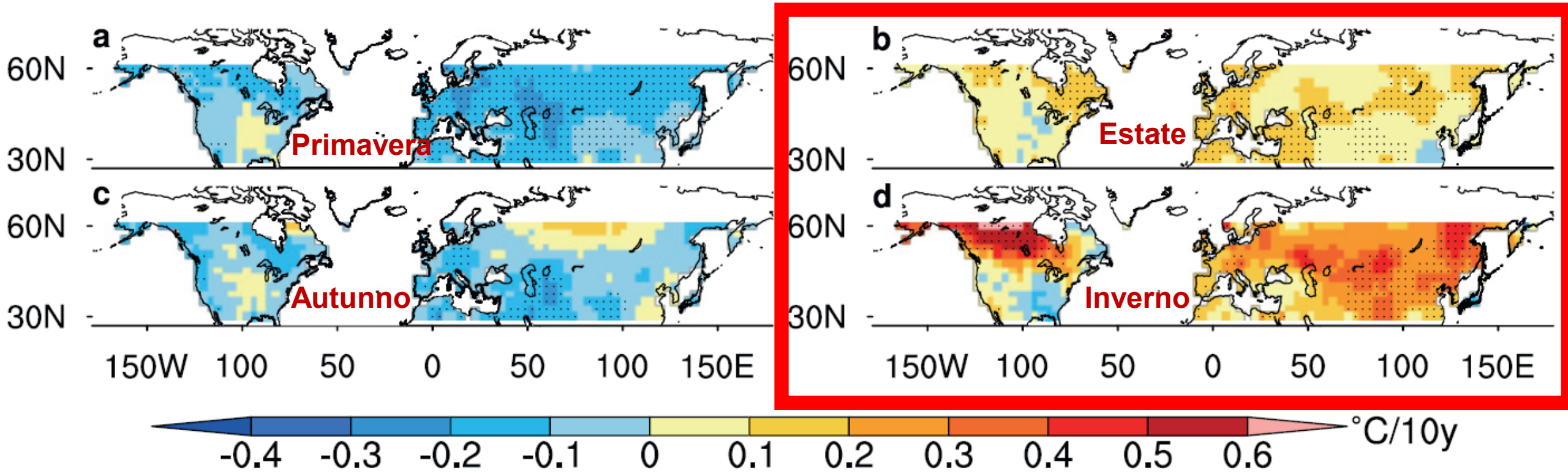


Key findings ***season onset*** (periodo 1951-2011)

- Anticipo primavera (1.6 d/10years)
- Anticipo estate (2.5 d/10years)
- Cambiamenti *onset* stagionali etereogenei con differenze regionali

Key findings temperature (periodo 1951-2011)

- Temperature sono aumentate significativamente nelle estati (più lunghe) [0.09 °C/10 years] e negli inverni (più corti) [0.26 °C/10 years]
- Aumento di temperature compatibile con l'aumento della frequenza Heat Waves
- Trend diffuso in Asia orientale
- Inverni in Nordamerica: aumento T 0.4 °C/10 years

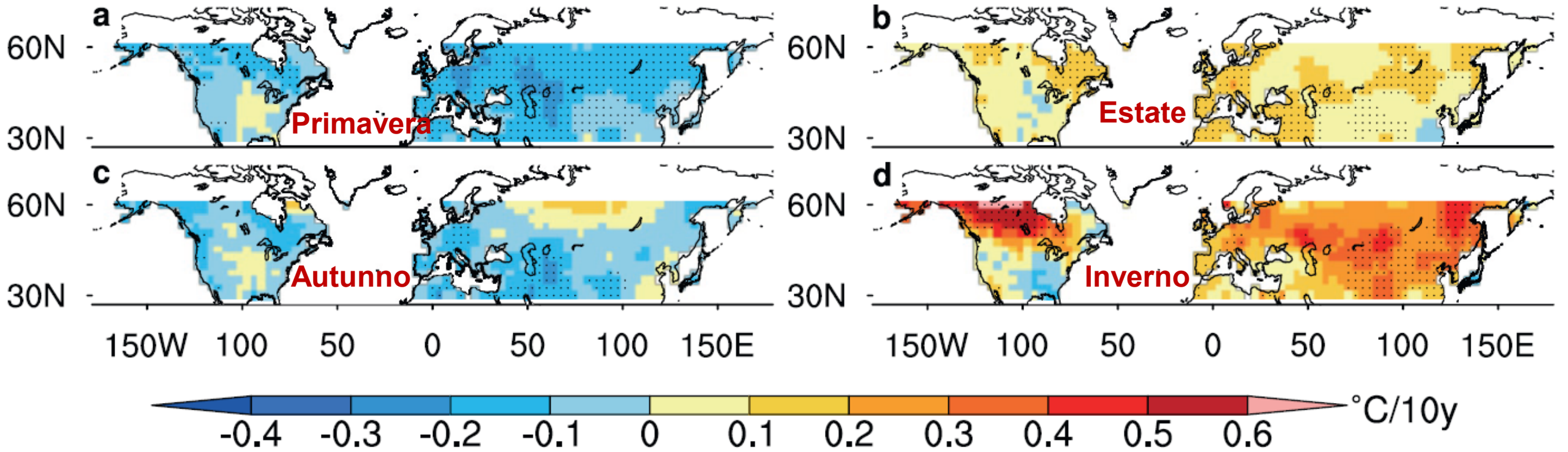


Key findings ***temperature*** (periodo 1951-2011)

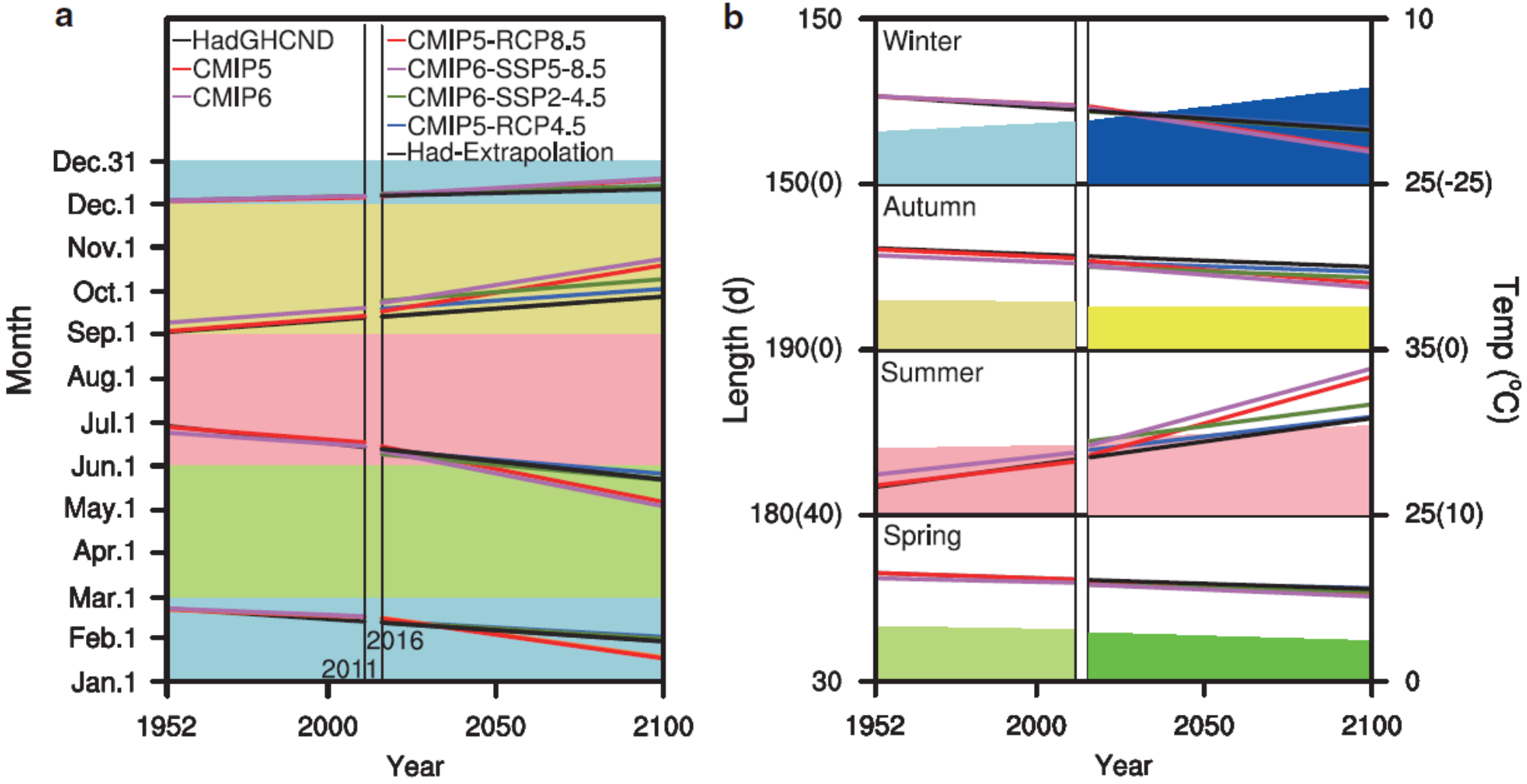
- Aumento frequenza, durata e magnitudo HW estive
- Estati più calde e più lunghe

Impatti

- Vegetazione e foreste (frequenza e durata *wildfires*)
- Elevate T compromettono salute mentale e fisica
- Aumento di *energy demand*
- Economie turistiche (stagione sciistiche)
- Aumento dell'anticipo di primavere più fredde porta alle ***false spring***
- Michigan (2012) persi 500 M $ per mancati raccolti

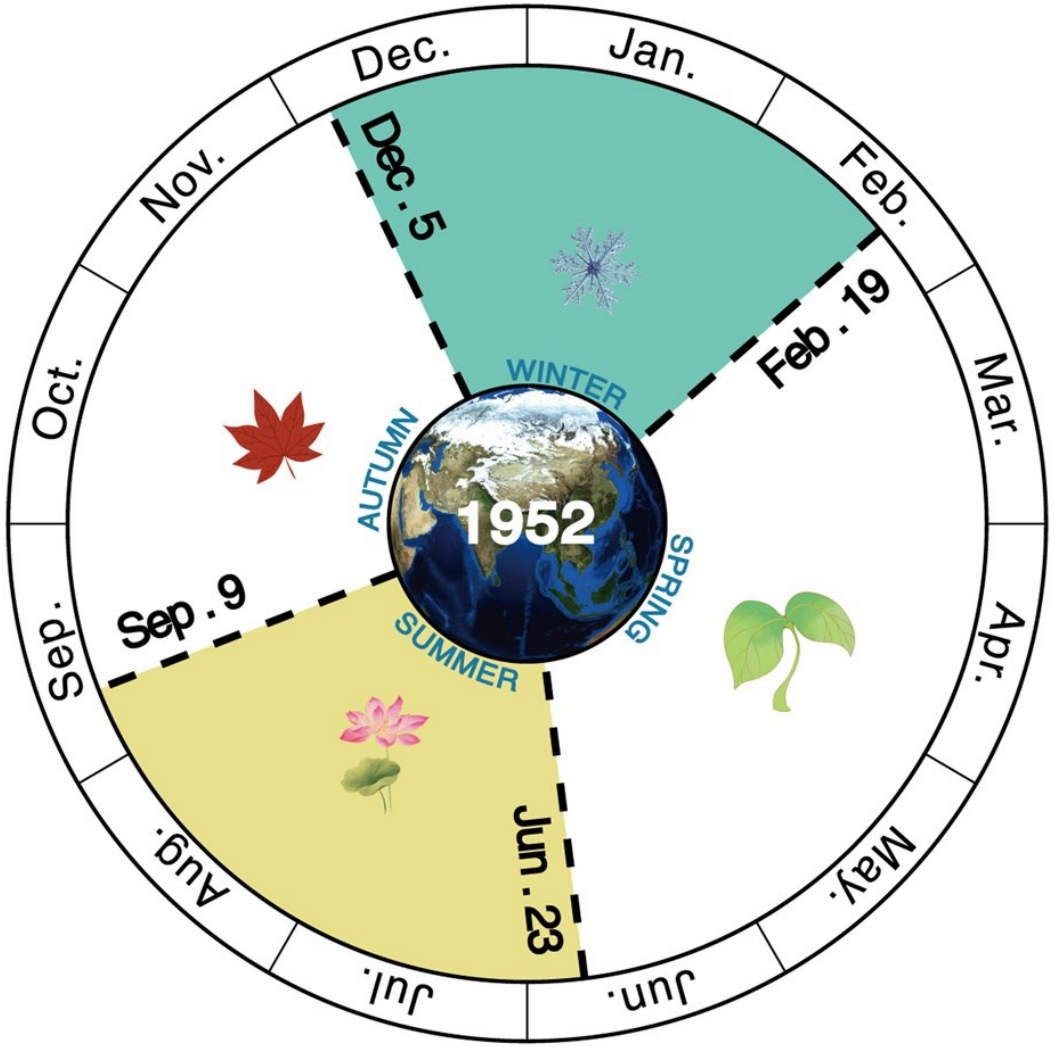


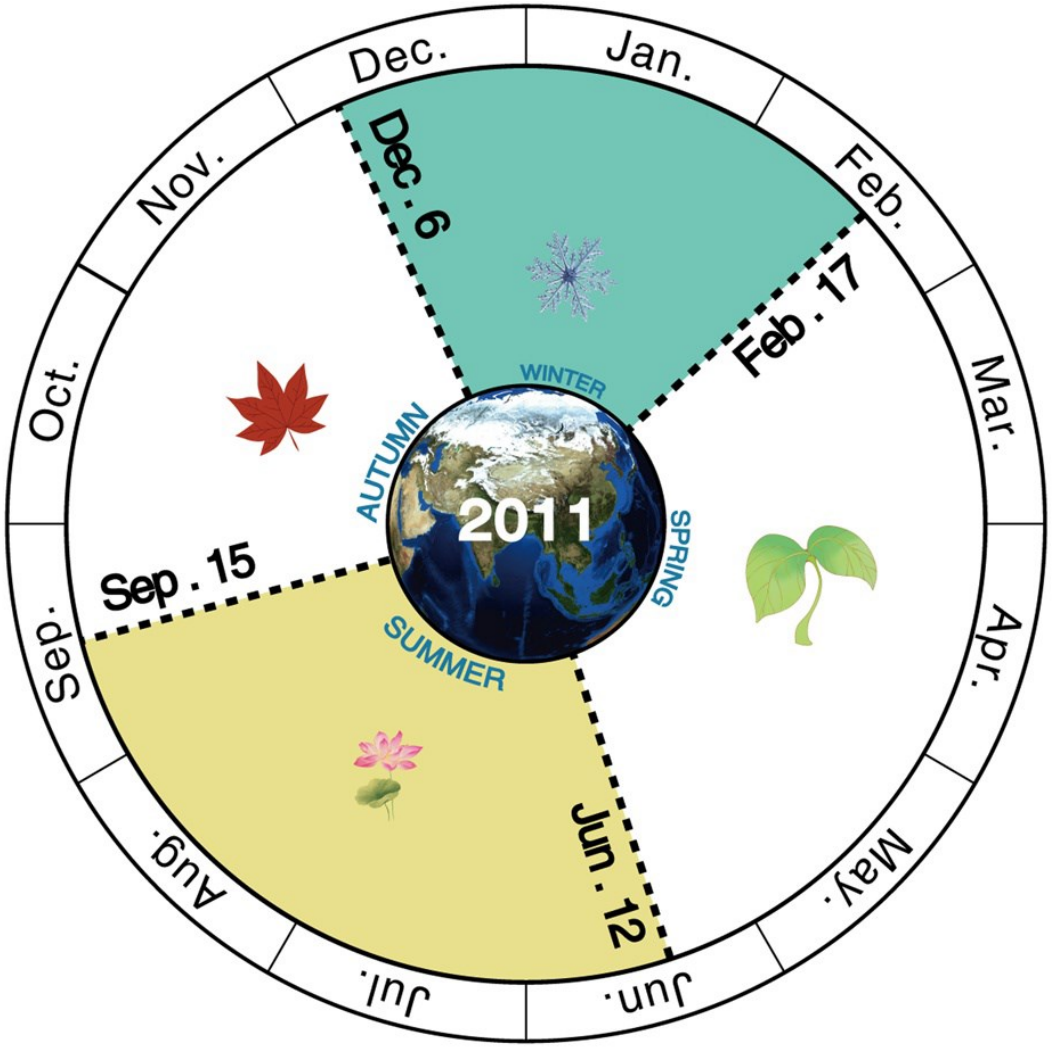
Elaborazioni e simulazioni di scenario al 2100 (RCP 4.5, RCP 8.5)



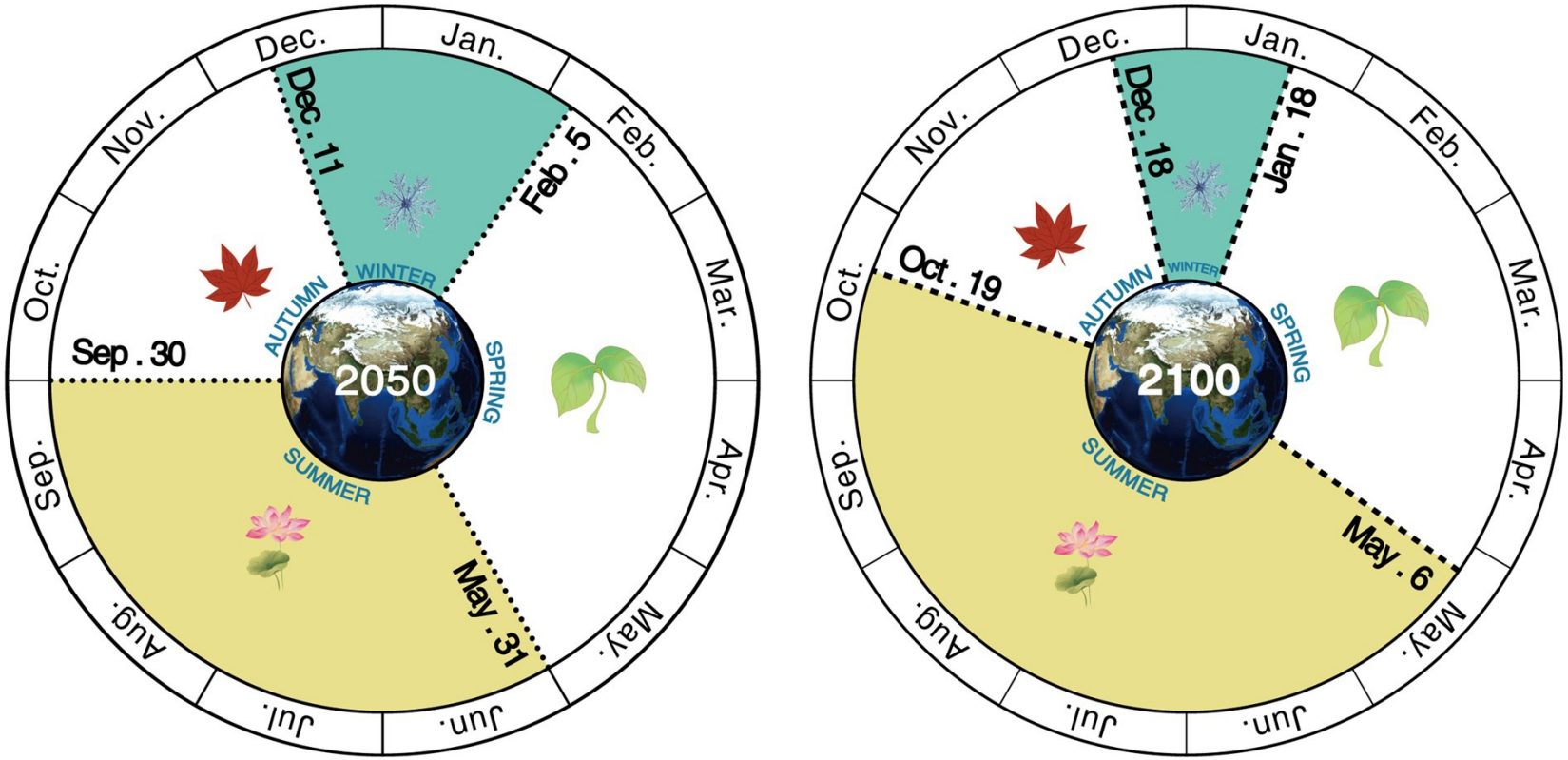
RCP 4.5: confermato il trend osservato nella serie storica ('longer summer and shorter winter will become the new normal in the 21st century')

Elaborazioni e simulazioni di scenario 1952-2011





Elaborazioni e simulazioni di scenario al 2100 (RCP 8.5)



RCP 8.5 (*busines-as-usual scenario*): 166 gg (estate), 31 gg (inverno)

- Estati molto più lunghe e più calde, inverni più corti e più caldi, primavere ed autunni più corti
- Primavera ed estate cominceranno 1 mese prima (rispetto al 2011), autunno ed inverno anticipo di 1 mese
- 6 mesi di estate, meno di 2 mesi di inverni
- Gli impatti più importanti ricadranno sull'economia agricola, sui sistemi ecologici (biodiversità) e sulla salute umana

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RESEARCH ARTICLE | CLIMATOLOGY

The emergence of heat and humidity too severe for human tolerance

COLIN RAYMOND , TOM MATTHEWS, AND , RADLEY M. HORTON Authors Info & Affiliations

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38.917 57

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