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FINNISH METEOROLOGICAL INSTITUTE

Climate science, methods and data

Achim Drebs

Senior scientist

Finnish Meteorological Institute



Space Climate School 6 on March 30 - April 3, 2016, Levi, Finland



Content

History of Climate

Physically basics of Climate

About climatological scales in time and space

Downscaling from global to local climate

Quantifying the climate

Climate classification

Climate data – historic, synoptic, **re-analysed**, satellite, radar

Climate data sources

Climatological applications



History of Climatology – Development of Instruments

Thermometer

- development in 16th and 17th centuries in Europe
- Galilei (I), Drebbel (NL), Fludd (GB), or Santorio (I)

Hygrometer

- first useful hygrometer Lambert (D), 1755.

Anemometer

- first description of an anemometer given by Alberti (I), 1450

Barometer

- Torricelli (I), 1643, and Berti (I), 1640/1643

Pluviometer

- Greeks, about 500 BCE; about 400 BCE people in India



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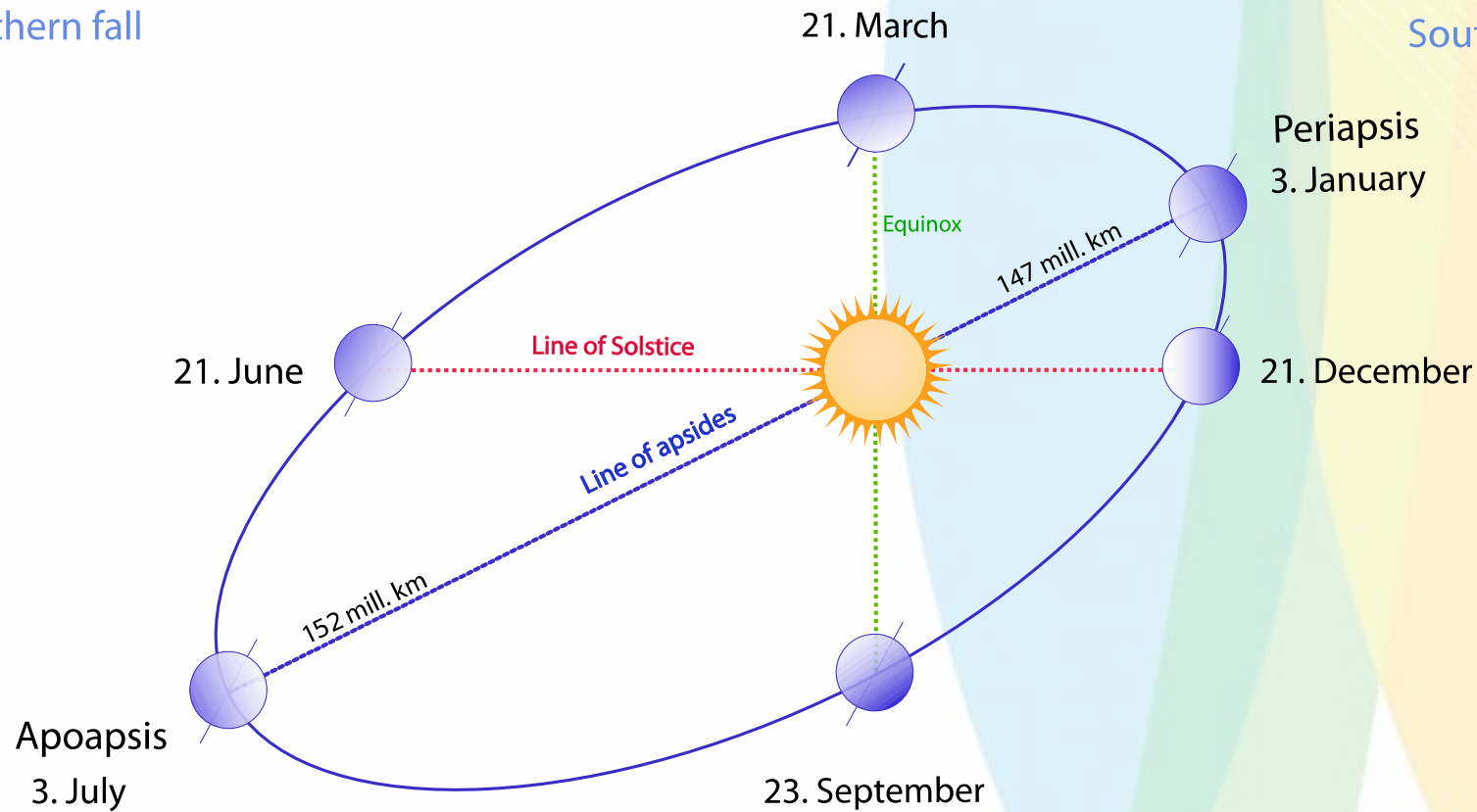
Physically basics of Climate - the Sun – Earth system



Lines of Solstice, apsides, Equinox

Northern spring/
Southern fall

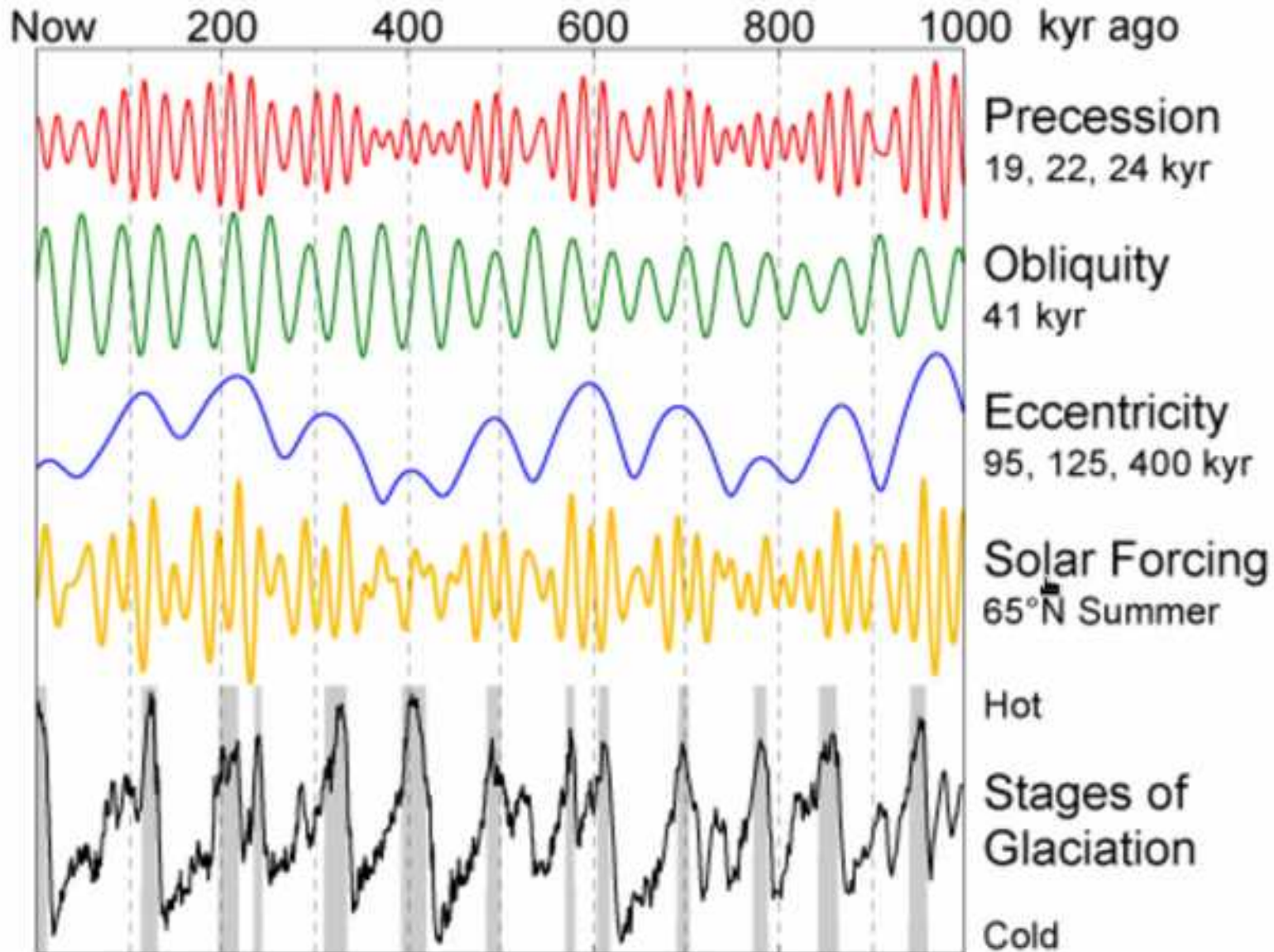
Northern winter/
Southern summer



Northern summer/
Southern winter

Northern fall/
Southern spring

Milankovitch cycles





earth's energy budget

The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (light and heat), that can be measured by CERES, and other components like conduction, convection, and evaporation which also transport heat from Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (from the sun) is the same as the amount going out (from reflection of sunlight and from emission of infrared radiation).

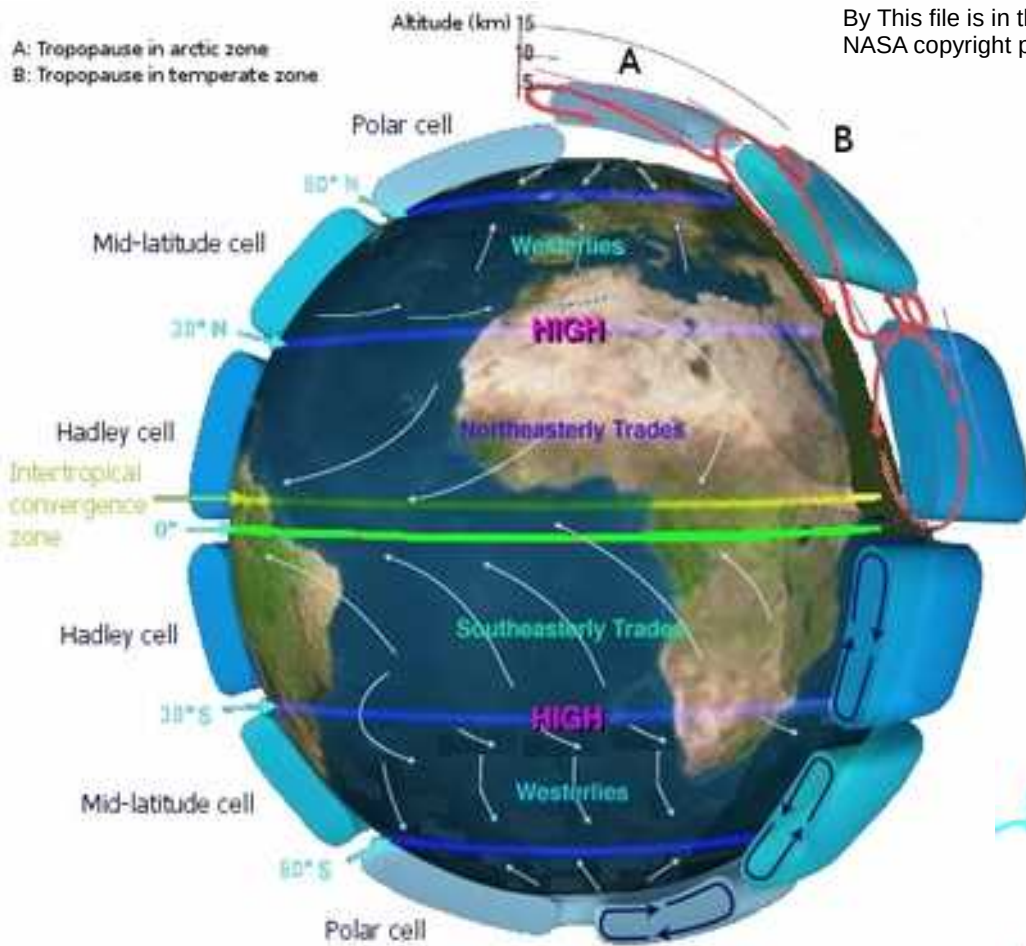


All values are fluxes in Wm²
and are average values based on ten years of data

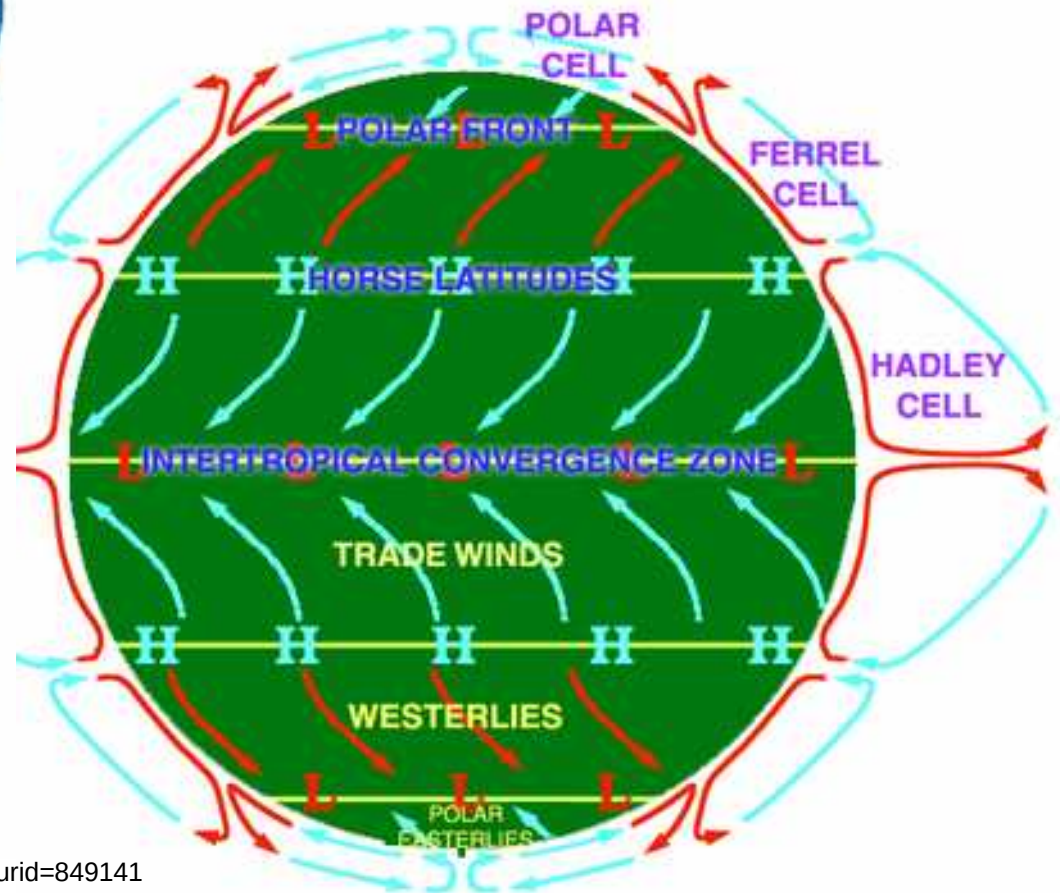
Loeb et al., J. Clim. 2009
Trenberth et al., BAMS, 2009

NP-2010-05-265-LaRC

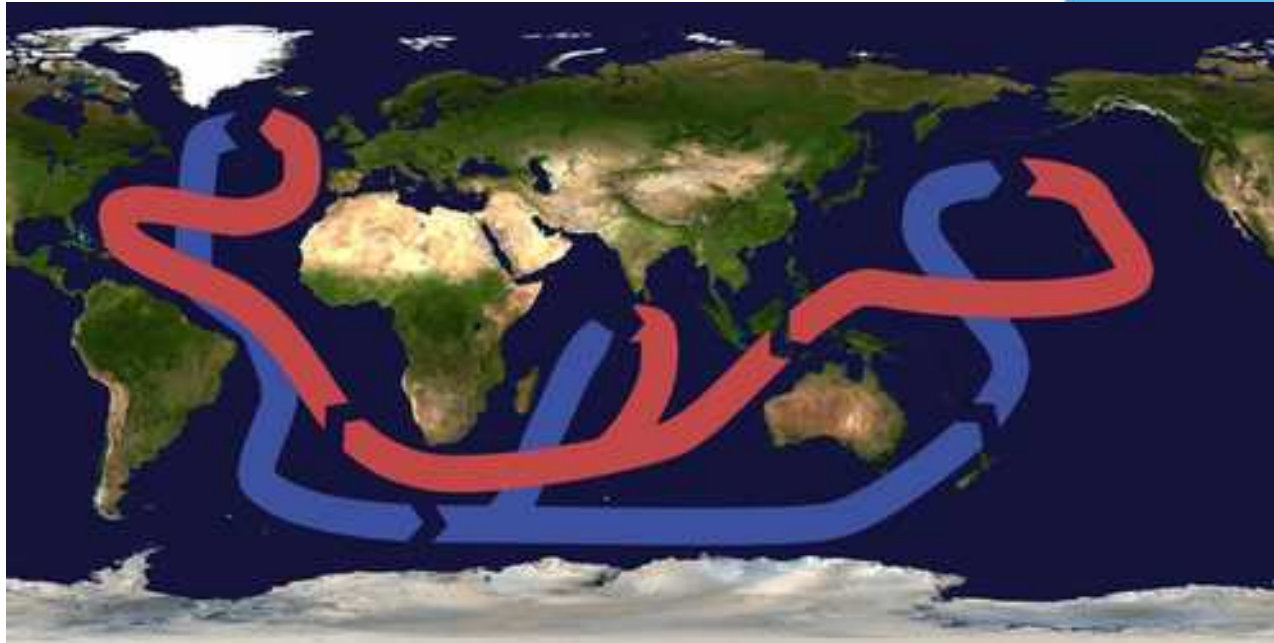
By This file is in the public domain in the United States because it was solely created by NASA. NASA copyright policy states that "NASA material is not protected by copyright unless noted".



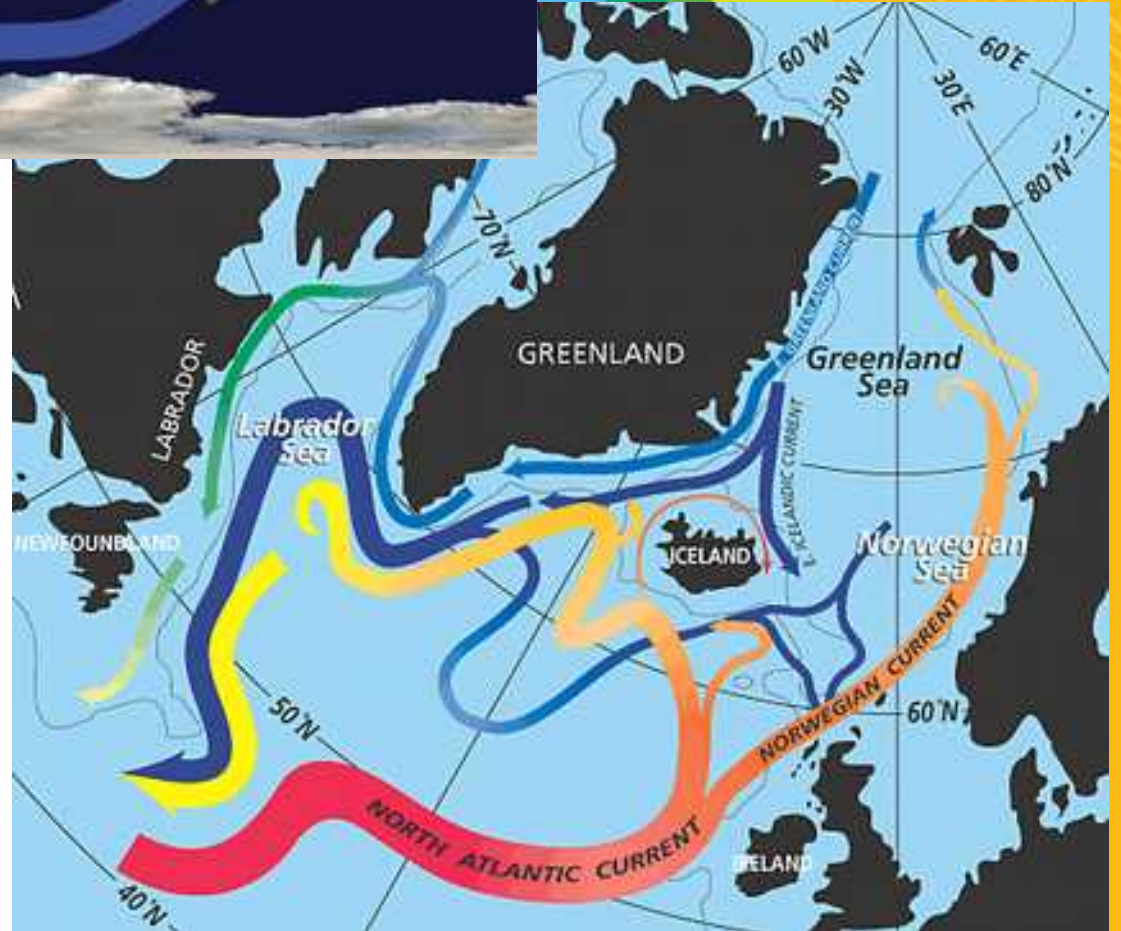
Atmospheric wind circulation



About 150 local wind systems

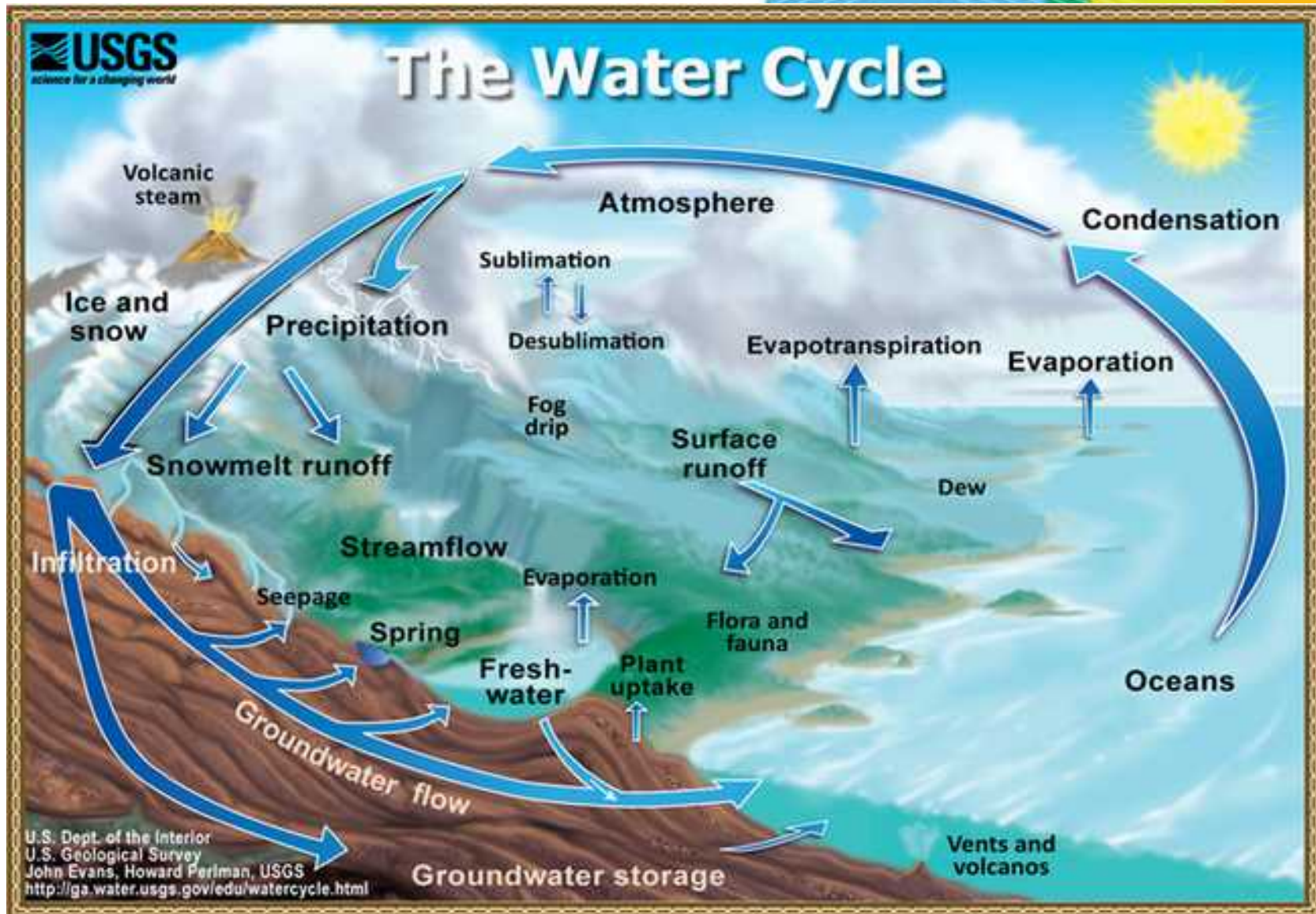


Earth's ocean circulation





Hydrosphere



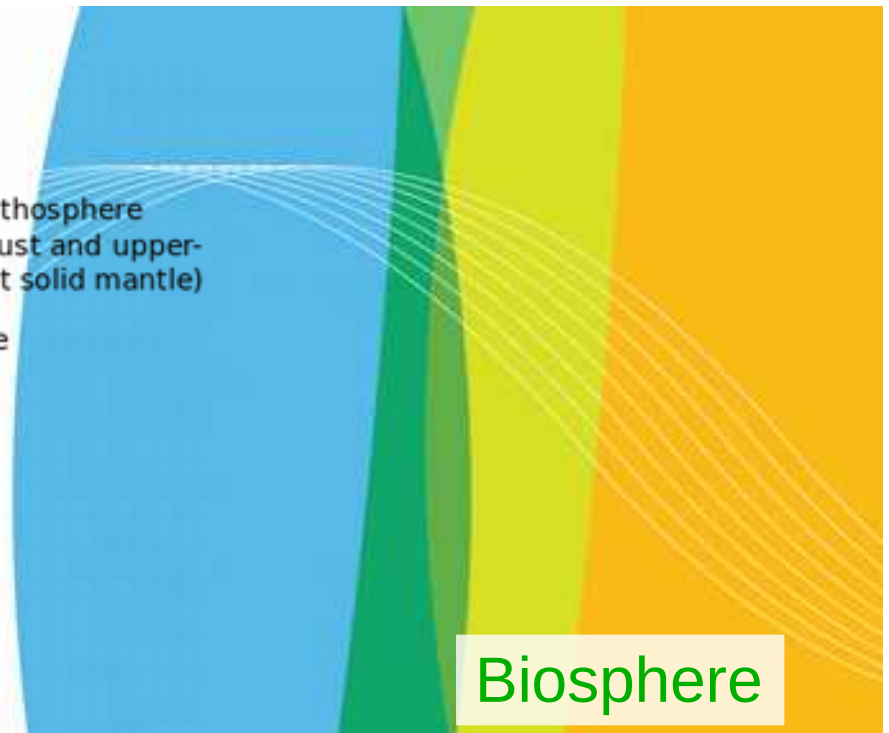
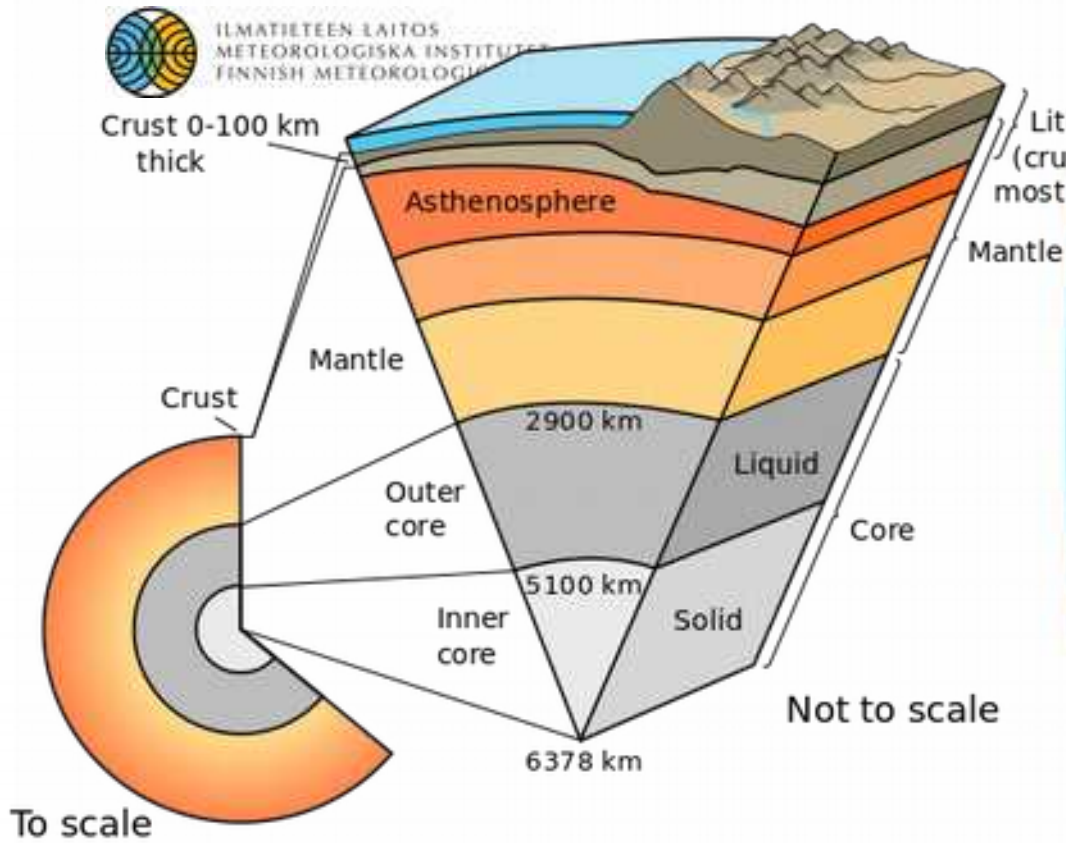
Cryosphere



- Snow
- Sea ice
- Ice shelves
- Ice sheets
- Glaciers and ice caps
- Permafrost, continuous
- Permafrost, discontinuous
- Permafrost, isolated



Lithosphere





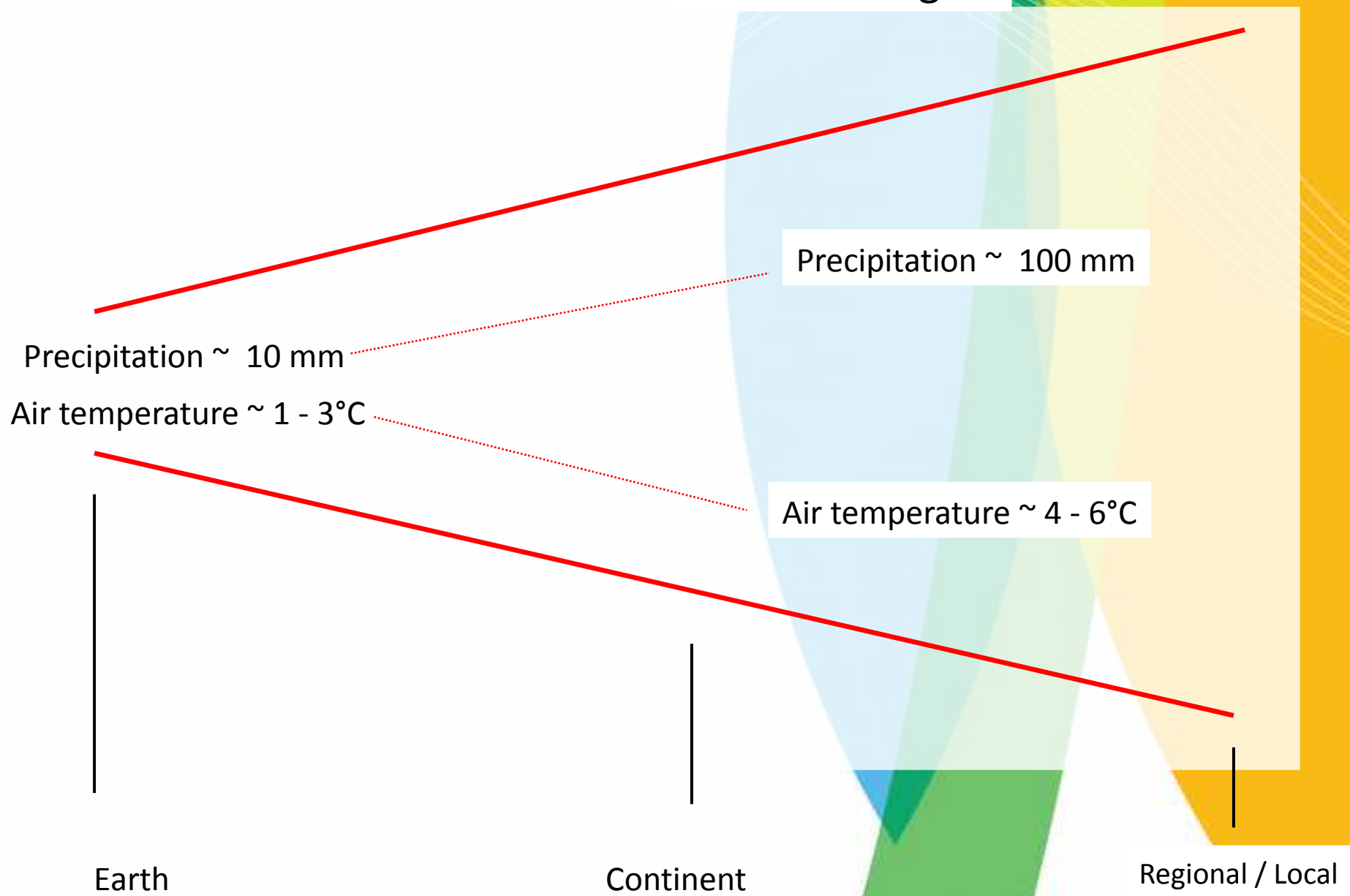
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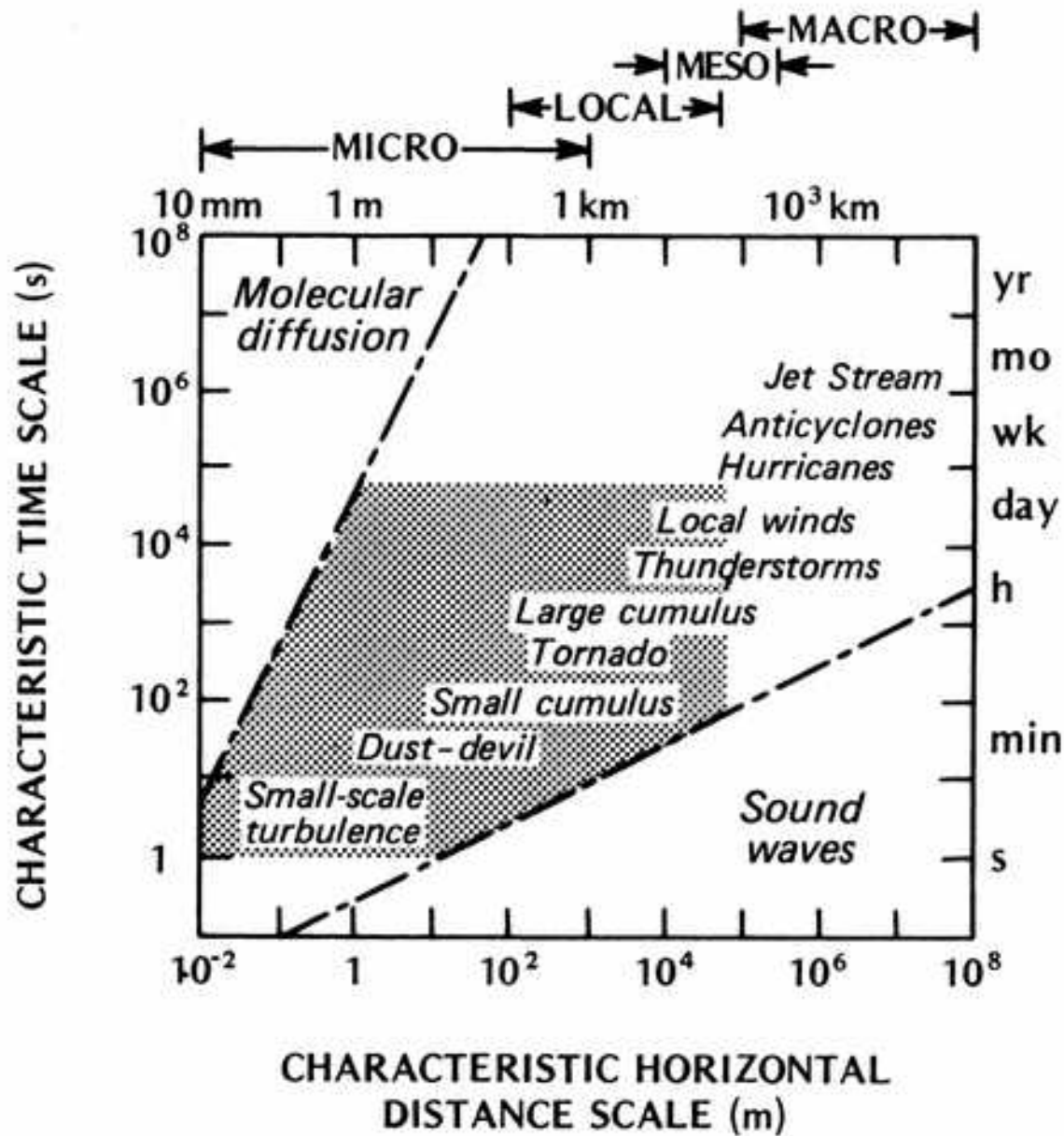
About climatological scales in time and space





About scaling ...







Climate <-> Weather

Climate is the statistics (usually, mean or variability) of weather, usually over a 30-year interval.

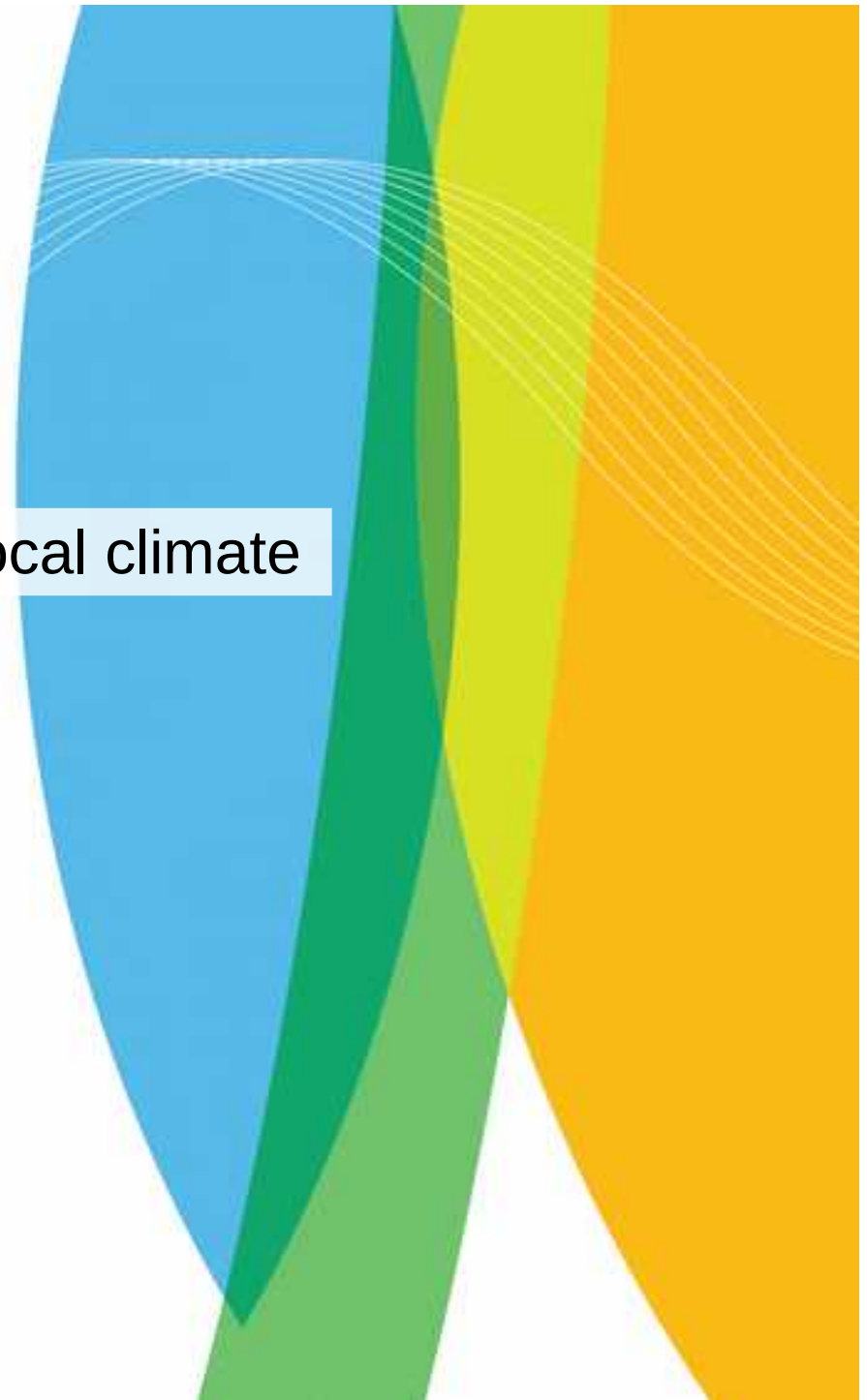
Standard normal period = 30-year period, defined by WMO, 1931 – 1960, 1961 – 1990, 1991 – 2020, ...

Normal period = 30-period, 1941 – 1970, 1951- 1980, 1961 – 1990, ...



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Downscaling from global to local climate

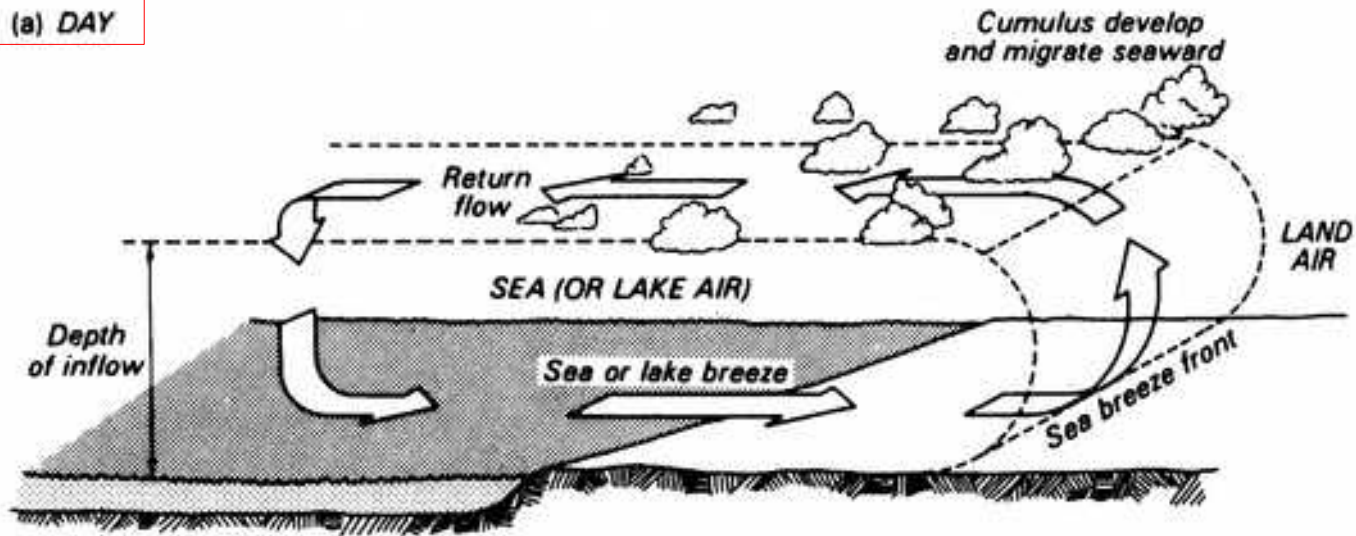


Land and sea breeze



ILMATHIETEEN SAIITOC
ME
TEN

(a) DAY



(b) NIGHT

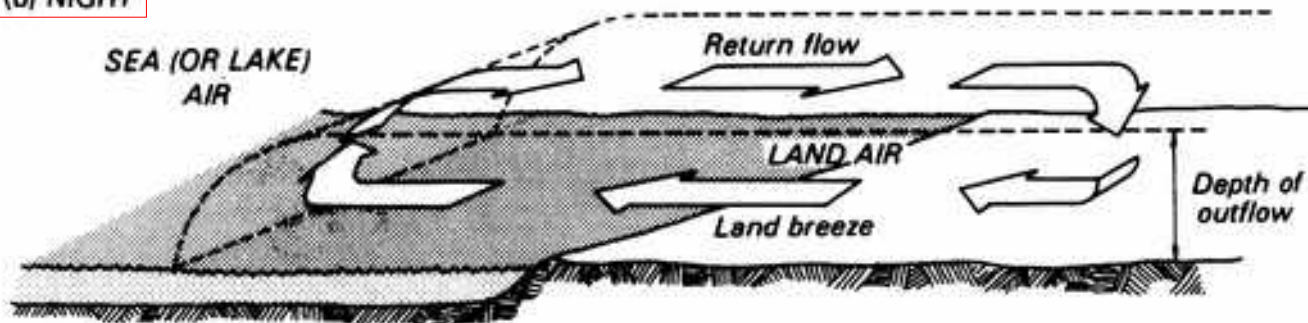
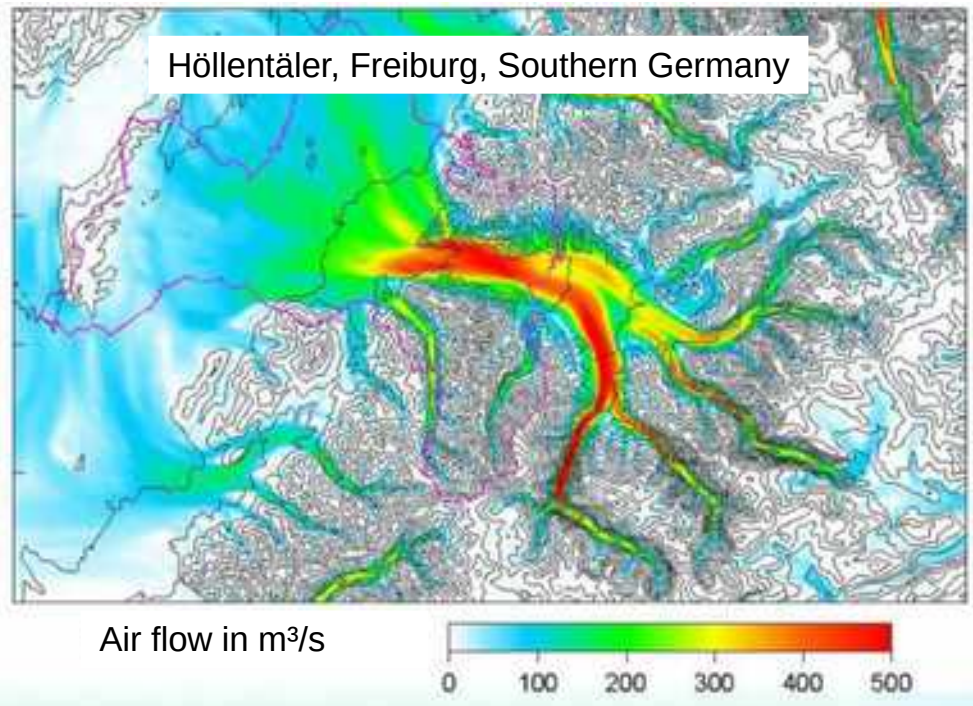
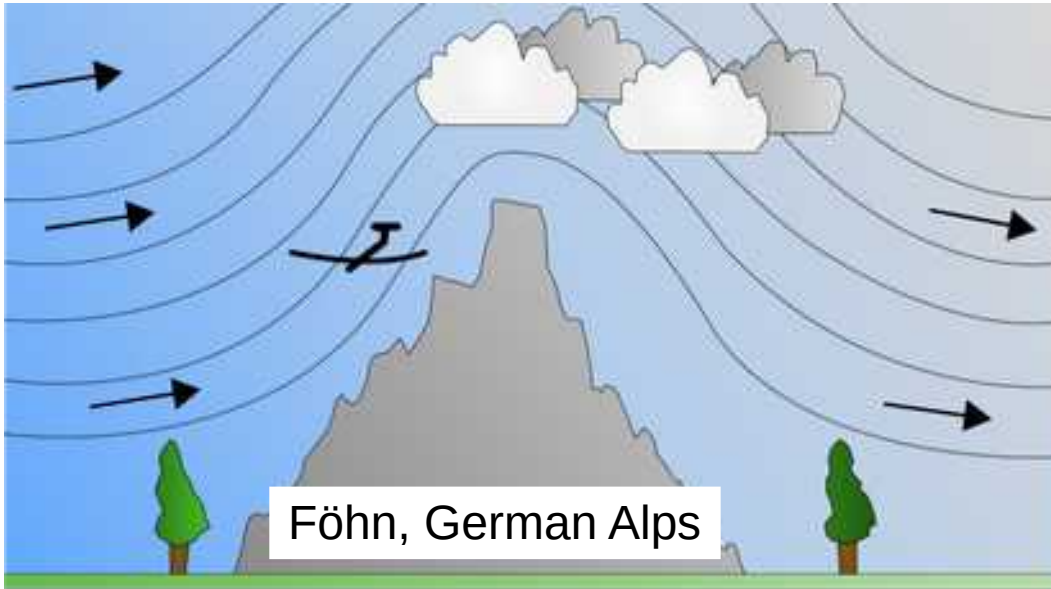


Figure 5.6 Land and sea (lake) breeze circulations across a shoreline (a) by day and (b) at night, during anticyclonic weather.



dry, cold, strong wind that occurs in Southern France

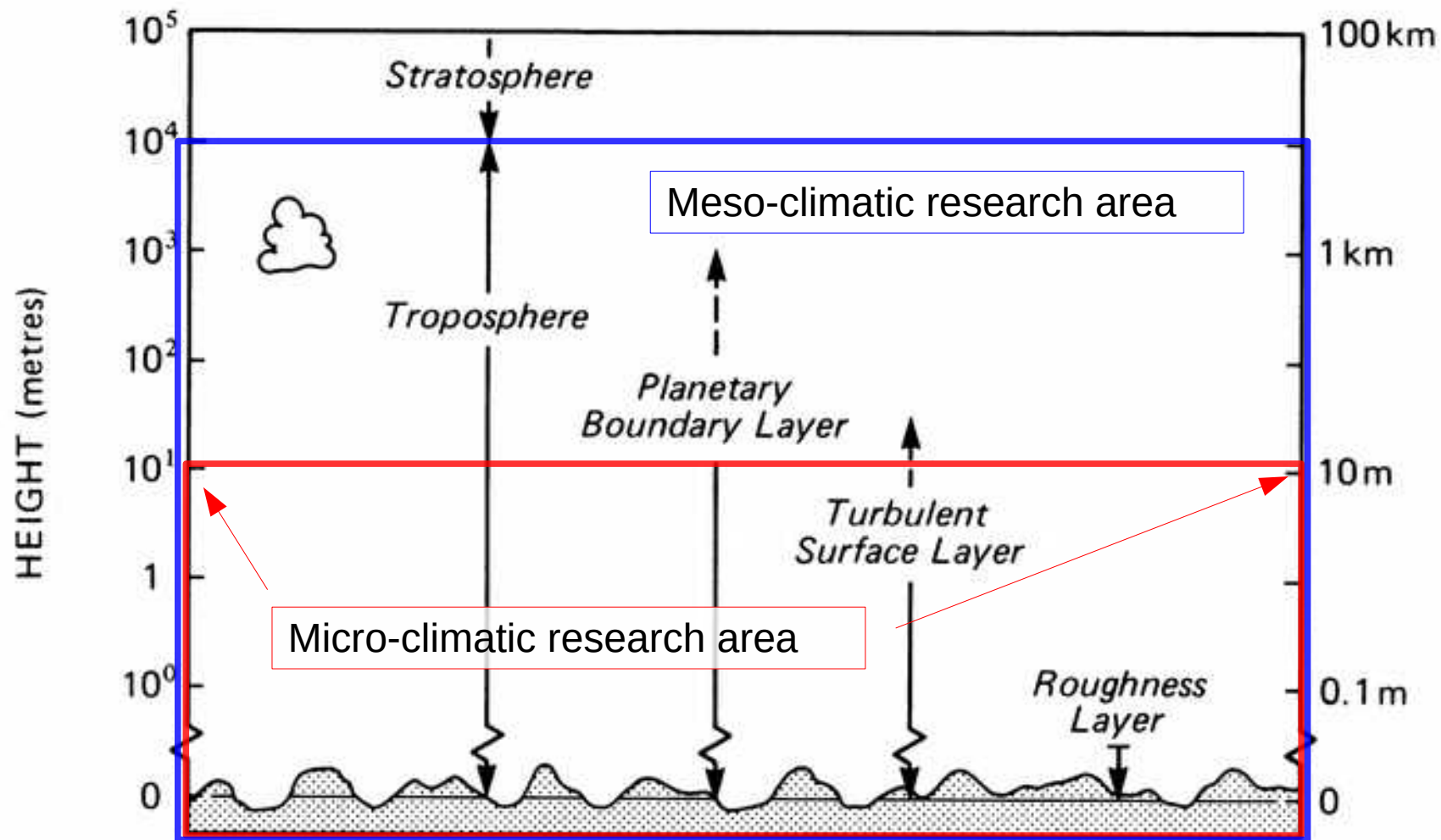
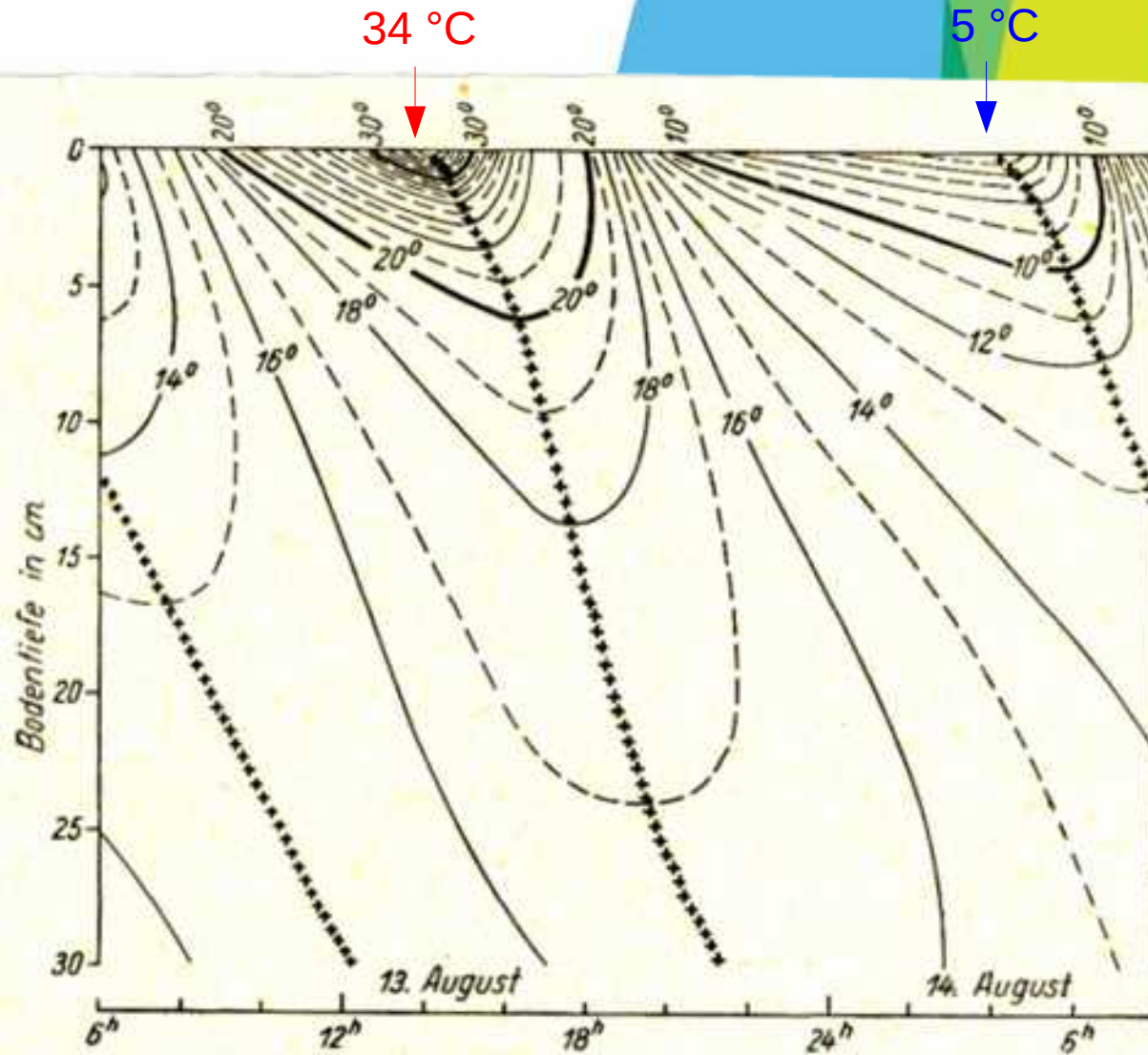


Figure 1.2 The vertical structure of the atmosphere.



depth

Abb. 20. Eindringen der täglichen Wärmewelle in den Boden an einen ungestörten Sommertag (nach Beobachtungen von Th. Homén in Finnland)

Soil temperature in Karjalohja, Finland, August 1893, Homén

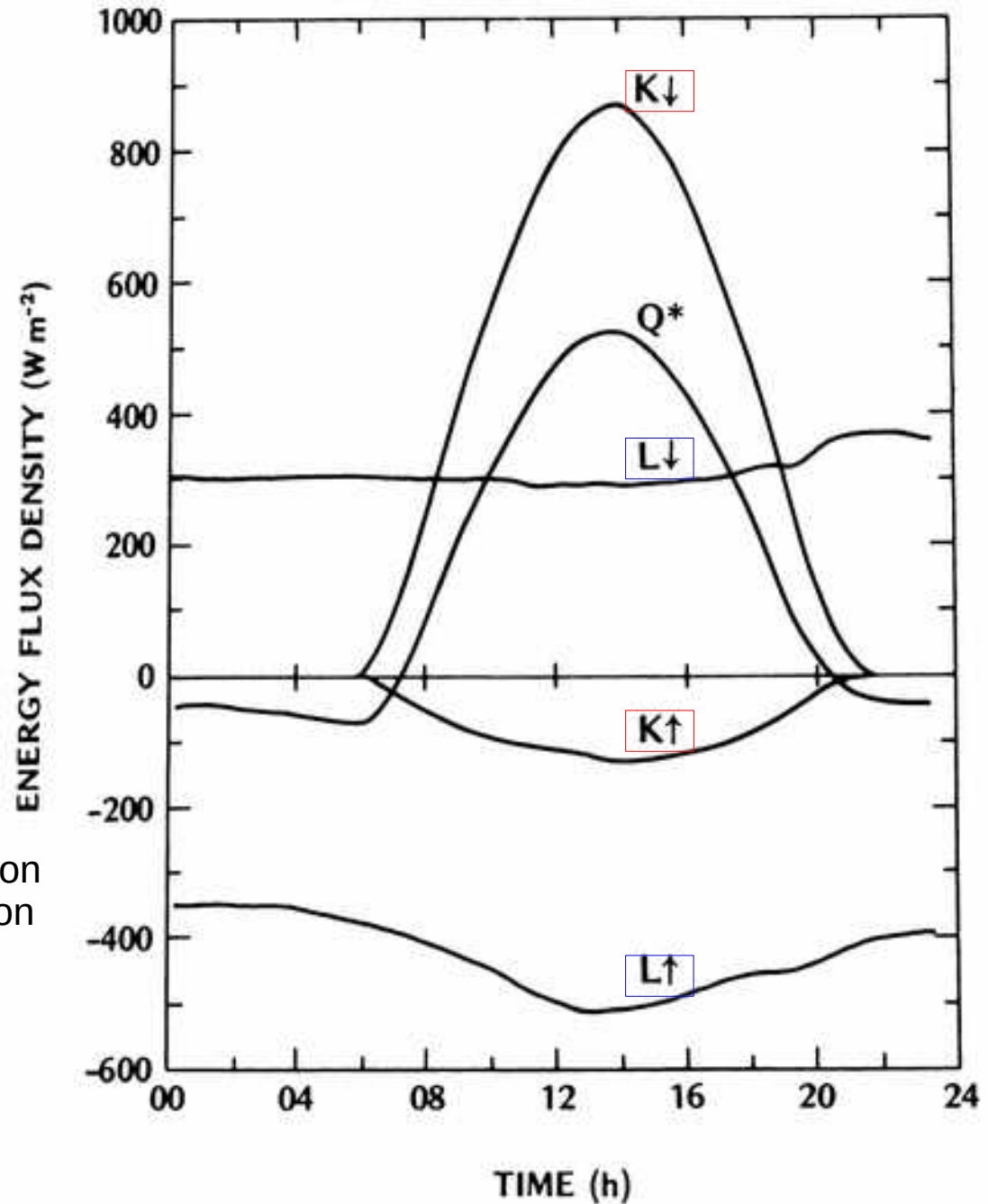


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Radiation budget components for 30 July 1971, at Matador, Saskatchewan (50 °N) over 0.2 m stand of native grass. Cloudless skies in the morning, increasing cloud in the later afternoon and evening (after Riply and Redmann, 1976).

$K\downarrow$ = short-wave incoming solar radiation
 $K\uparrow$ = short-wave reflected solar radiation
 $L\downarrow$ = long-wave incoming radiation
 $L\uparrow$ = long-wave outgoing radiation

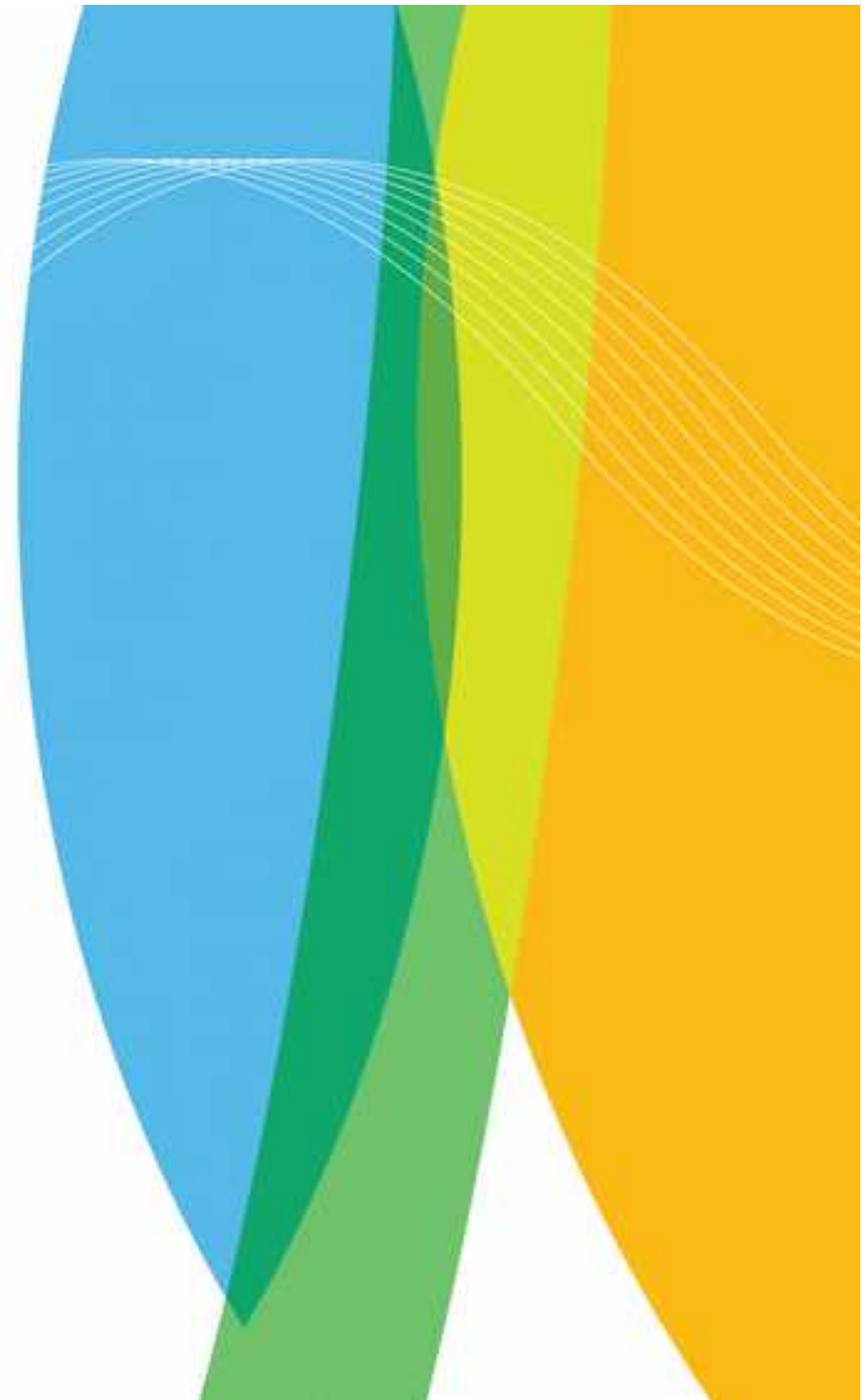
$$Q^* = K\downarrow - (K\uparrow + L\downarrow + L\uparrow)$$





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Quantifying the climate





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Automatic weather station sites (Finland, left; Germany, right)

Air temperature



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Climatological parameter based on air temperature observations

Averages: daily, monthly, seasonally, yearly, ...

Extremes: maxima, minima (daily, monthly, yearly, ...)

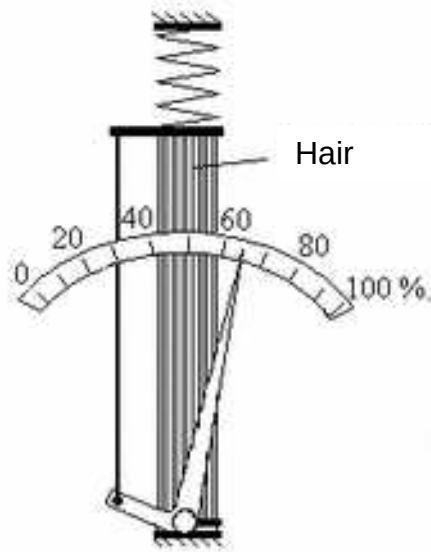
Number of days with

- $T_{\min} < -10\text{ }^{\circ}\text{C}$, cold day
- $T_{\min} < 0\text{ }^{\circ}\text{C}$, frost day
- $T_{\min} > 20\text{ }^{\circ}\text{C}$, tropical night
- $T_{\text{avg}} < 0\text{ }^{\circ}\text{C}$, winterday
- $T_{\max} < 0\text{ }^{\circ}\text{C}$, ice day
- $T_{\max} > 25\text{ }^{\circ}\text{C}$, summerday
- $T_{\max} > 30\text{ }^{\circ}\text{C}$, hot day
- $T_{\text{avg}} > 5\text{ }^{\circ}\text{C}$, growing season day
- $T_{\text{avg}} < 12/15\text{ }^{\circ}\text{C}$, heating day

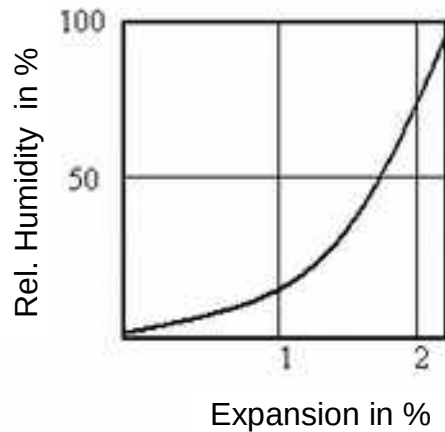
Return periods

Humidity

Hair hygrometer



Expansion of the hair



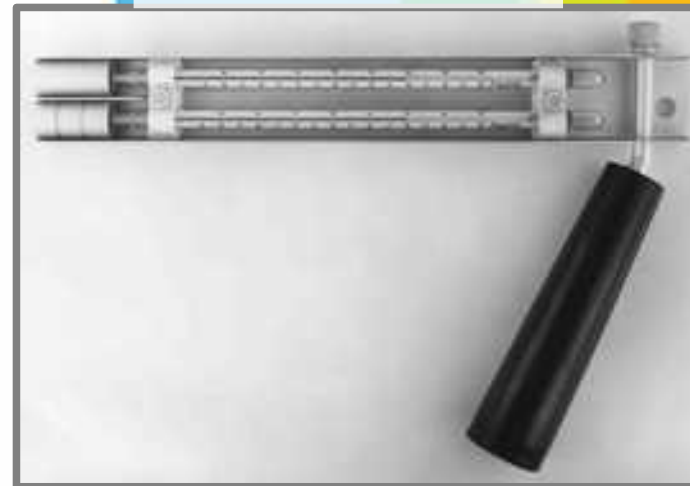
© <https://commons.wikimedia.org/w/index.php?curid=11105109>

Temperature and humidity sensor (rotronic hygroscope DV-2)



© Harke, de.wikipedia.org, 2016

Sling thermometer



© Thermo-Schneider, 2016

Climatological parameter based on humidity observation – absolute, relative humidity

Wind, direction and speed



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<https://commons.wikimedia.org/w/index.php?curid=4668794>

Climatological parameter based on wind observation

Averages: daily, monthly, seasonally, yearly, ...

Extremes: maxima, minima (daily, monthly, yearly, ...)

Number of days with wind speed ≥ 8 Beaufort, >21 m/s

Precipitation – rain and snow

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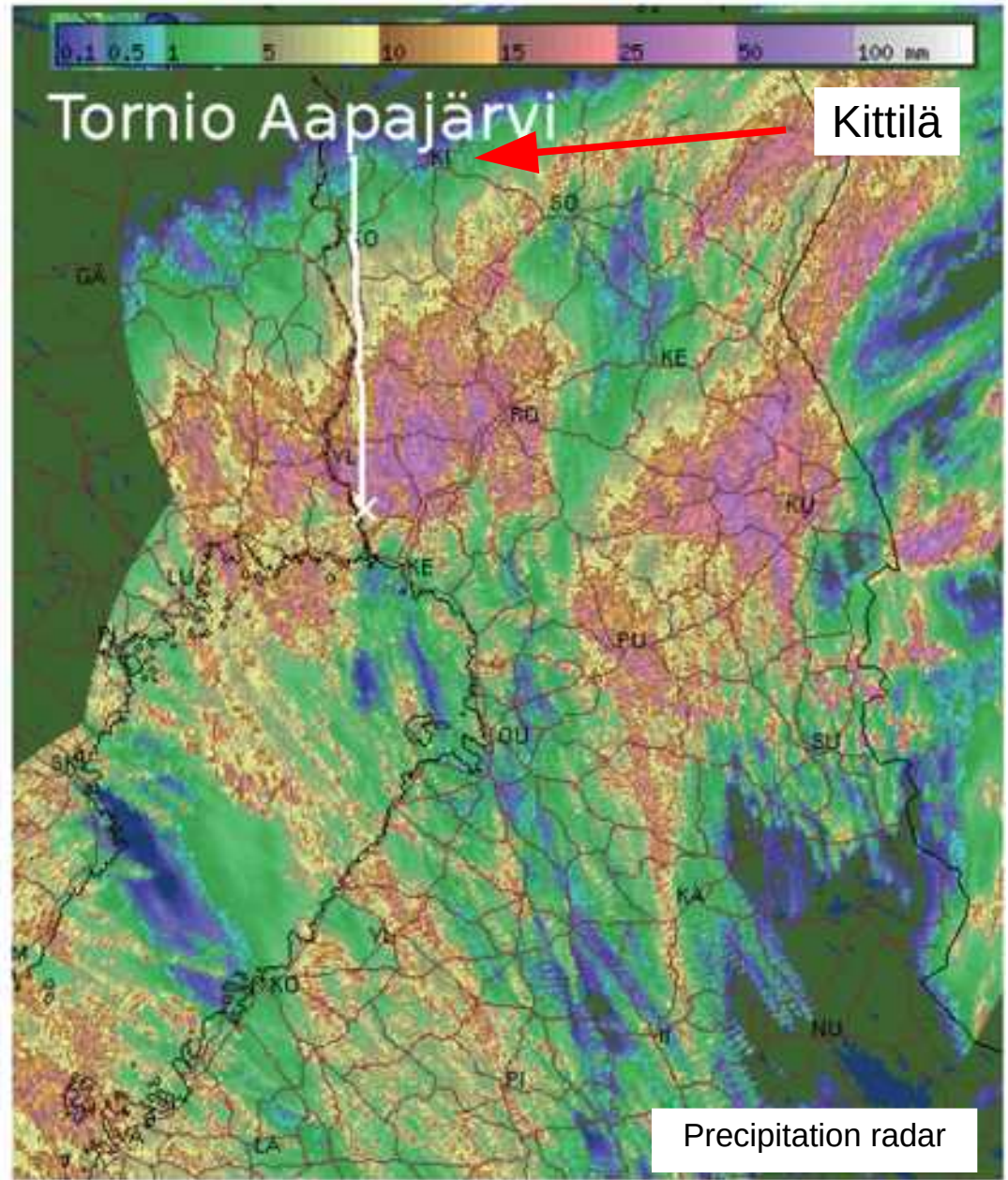


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© wikipedia, 2014

weighing-type precipitation gauge



© Finnish Meteorological Institute, 2011

Heavy rain event in Northern Finland, 24.7.2011,
121.3 mm measured at Tornio Aapajärvi



Climatological parameter based on precipitation observations

Sums: daily, monthly, seasonally, yearly, ...

Extremes: maxima (daily, monthly, yearly, ...)

Number of days with

- $R > 0.0$ mm
- $R \geq 1.0$ mm
- $R \geq 10.0$ mm
- $R \geq 20.0$ mm, heavy rain

Thunderstorm

Number of days with precipitation **less** than xx mm, dry spell
more than xx mm

Return periods

Precipitation – rain and snow



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Snow stick

© Finnish Meteorological Institute, 2016



Ultra-sonic sensor

© Finnish Meteorological Institute, 2016



Climatological parameter based on snow cover observations

Sums: snow cover monthly, seasonally, yearly, ...

Extremes: maxima snow depth (daily, monthly, yearly, ...)

Number of days with snow cover

Date of first snowfall

Date of first snow cover (depth > 1 cm)

Start of permanent snow cover, end of permanent snow cover (depth > 1 cm)

Date of ground snow free in open and forested areas

Snow density and water equivalent measurement

Return periods



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Cloudiness and visibility

CLOUDS ATLAS



High Troposphere	Medium Troposphere	Low Troposphere	Spreading vertical & Other-Accumulus clouds	Surface based
Cl sup	Al sup	Cl sup	Cl sup	Cl sup
Cl hb	Al hb	Cl hb	Cl hb	Cl hb
Cl med	Al med	Cl med	Cl med	Cl med
Cl lo	Al lo	Cl lo	Cl lo	Cl lo
Cl ne	Al ne	Cl ne	Cl ne	Cl ne
Cl ni	Al ni	Cl ni	Cl ni	Cl ni
Cl nu	Al nu	Cl nu	Cl nu	Cl nu
Cl pl	Al pl	Cl pl	Cl pl	Cl pl
Cl ps	Al ps	Cl ps	Cl ps	Cl ps
Cl sp	Al sp	Cl sp	Cl sp	Cl sp
Cl ss	Al ss	Cl ss	Cl ss	Cl ss
Cl ts	Al ts	Cl ts	Cl ts	Cl ts
Cl vc	Al vc	Cl vc	Cl vc	Cl vc
Cl vl	Al vl	Cl vl	Cl vl	Cl vl
Cl vr	Al vr	Cl vr	Cl vr	Cl vr
Cl vs	Al vs	Cl vs	Cl vs	Cl vs
Cl vt	Al vt	Cl vt	Cl vt	Cl vt

Ceilometer



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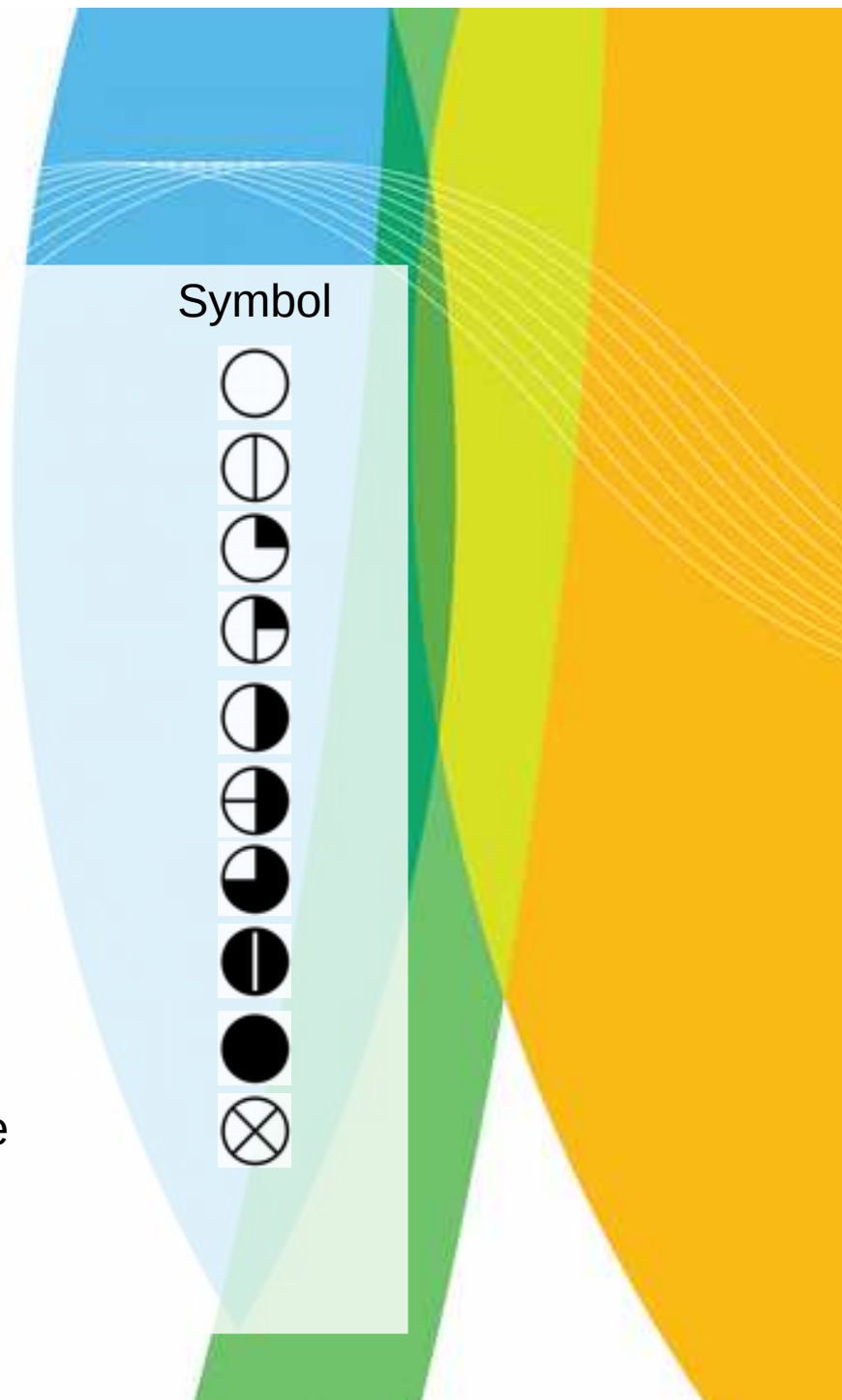
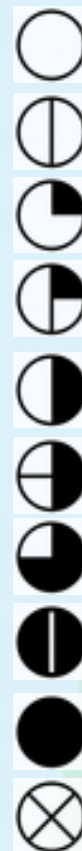
Present weather sensor



Cloud cover

0/8	...
1/8	sunny
2/8	partly cloudy
3/8	partly cloudy
4/8	partly cloudy
5/8	partly cloudy
6/8	cloudy
7/8	cloudy
8/8	overcast
9/8	sky not visible

Symbol





Climatological parameter based on cloudiness and visibility observations

Sums: cloud cover daily, monthly, seasonally, yearly, ...

Number of days with clear sky, cloudy sky
fog

Visibility measurements in miles, km, using land marks (lights at night)

Observation of cloud types and cloud heights, aeronautically purpose

Return periods

Solar short-wave radiation

Terrestrial long-wave radiation

.....

Radiosonde, T, RH, p, wind

Satellites

.....

Air pressure, p

Evapotranspiration



Radiosonde launch

© <http://www.zfx.de/sonde/>



Net radiometer

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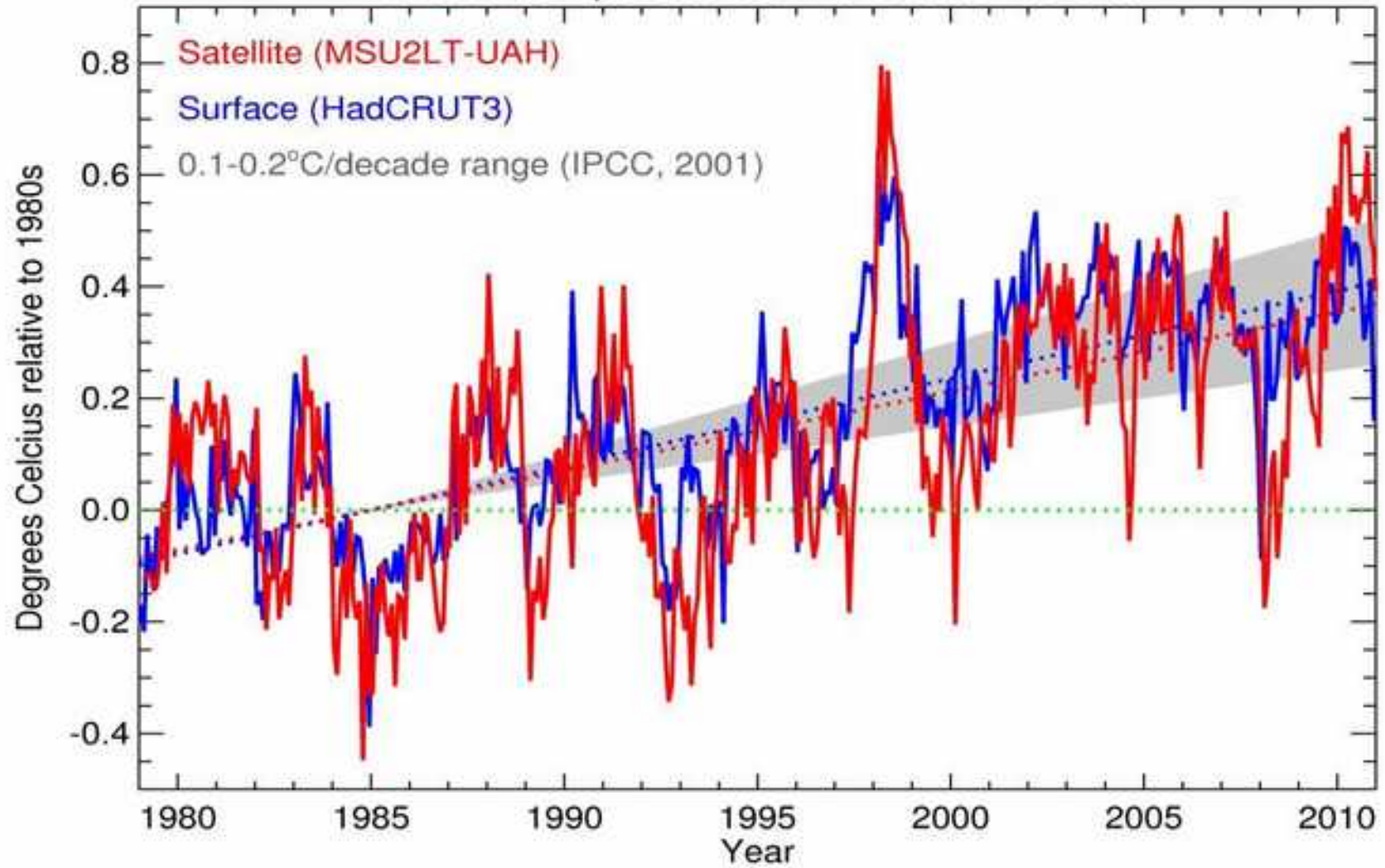


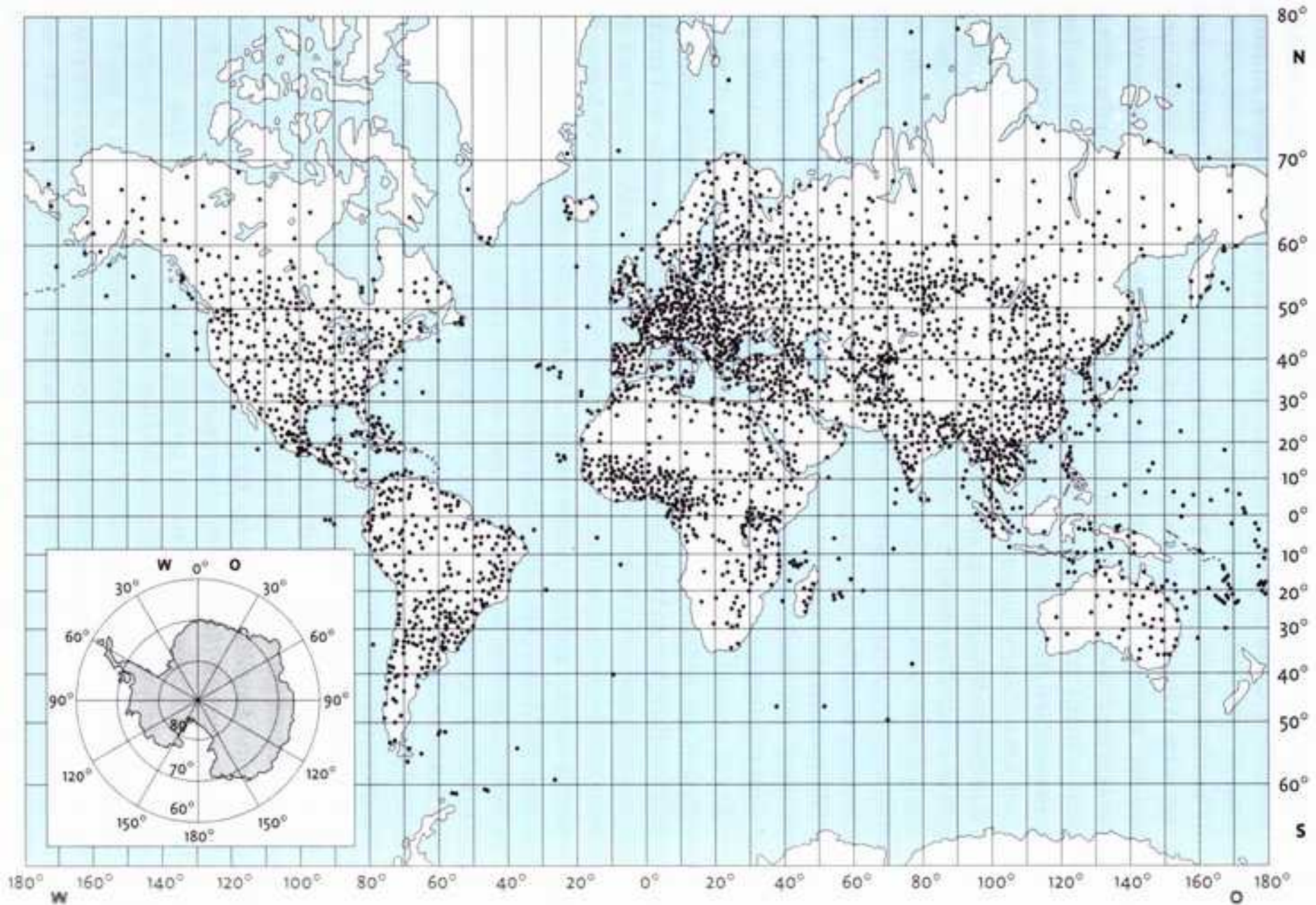
GEOS – 8, US – weather satellite

© <https://commons.wikimedia.org/w/index.php?curid=2902398>



Global temperatures in the satellite era





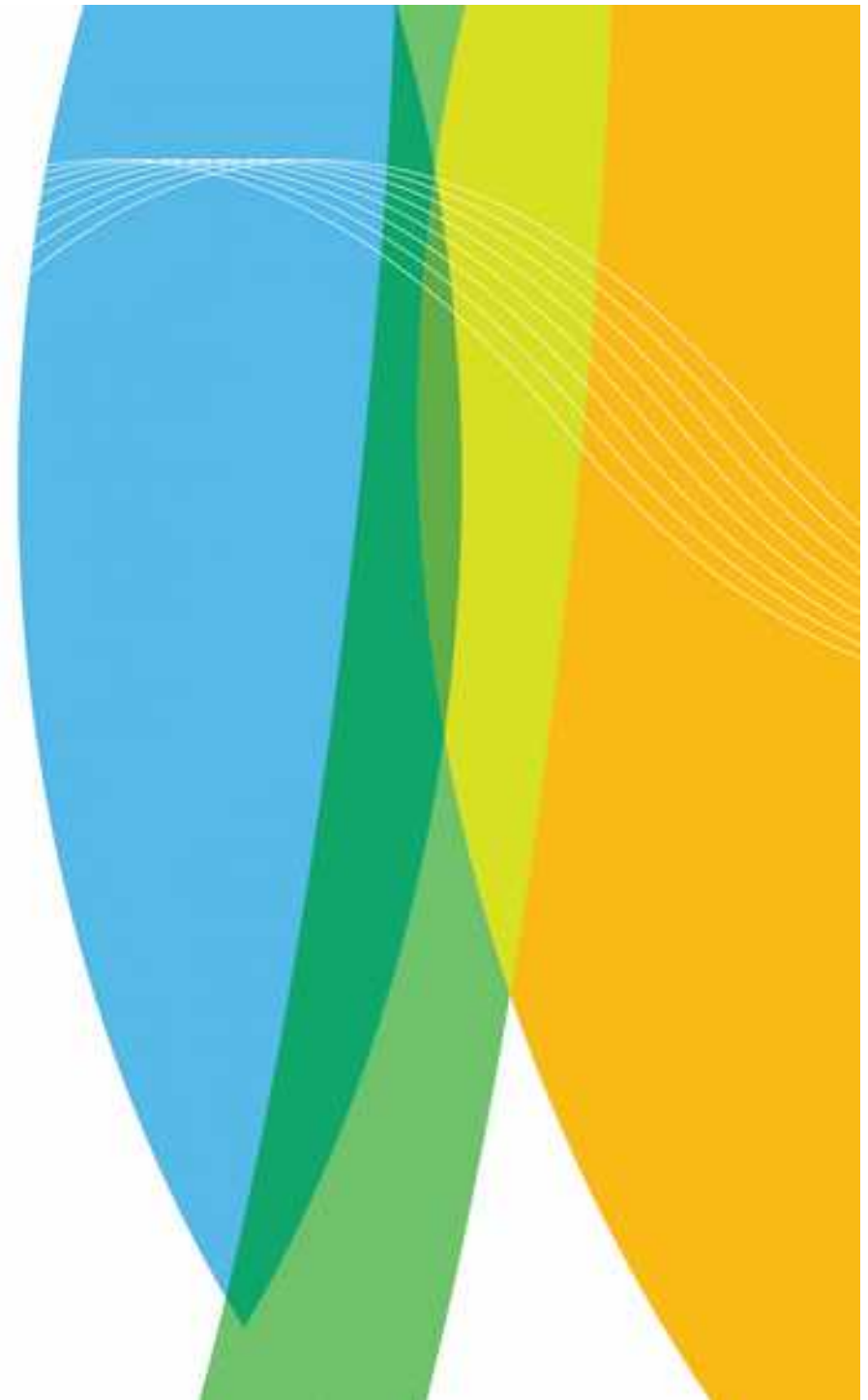
Global network of ground weather stations, after WMO 1981

In: Schönwiese (2008), Klimatologie, UTB 1793, page 88



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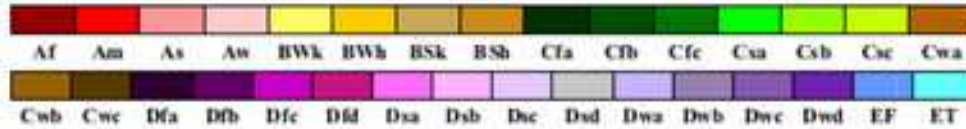
Climate classification



Empiric climate systems

World Map of Köppen–Geiger Climate Classification

updated with CRU TS 2.1 temperature and VASCLIM0 v1.1 precipitation data: 1951 to 2000



Main climates

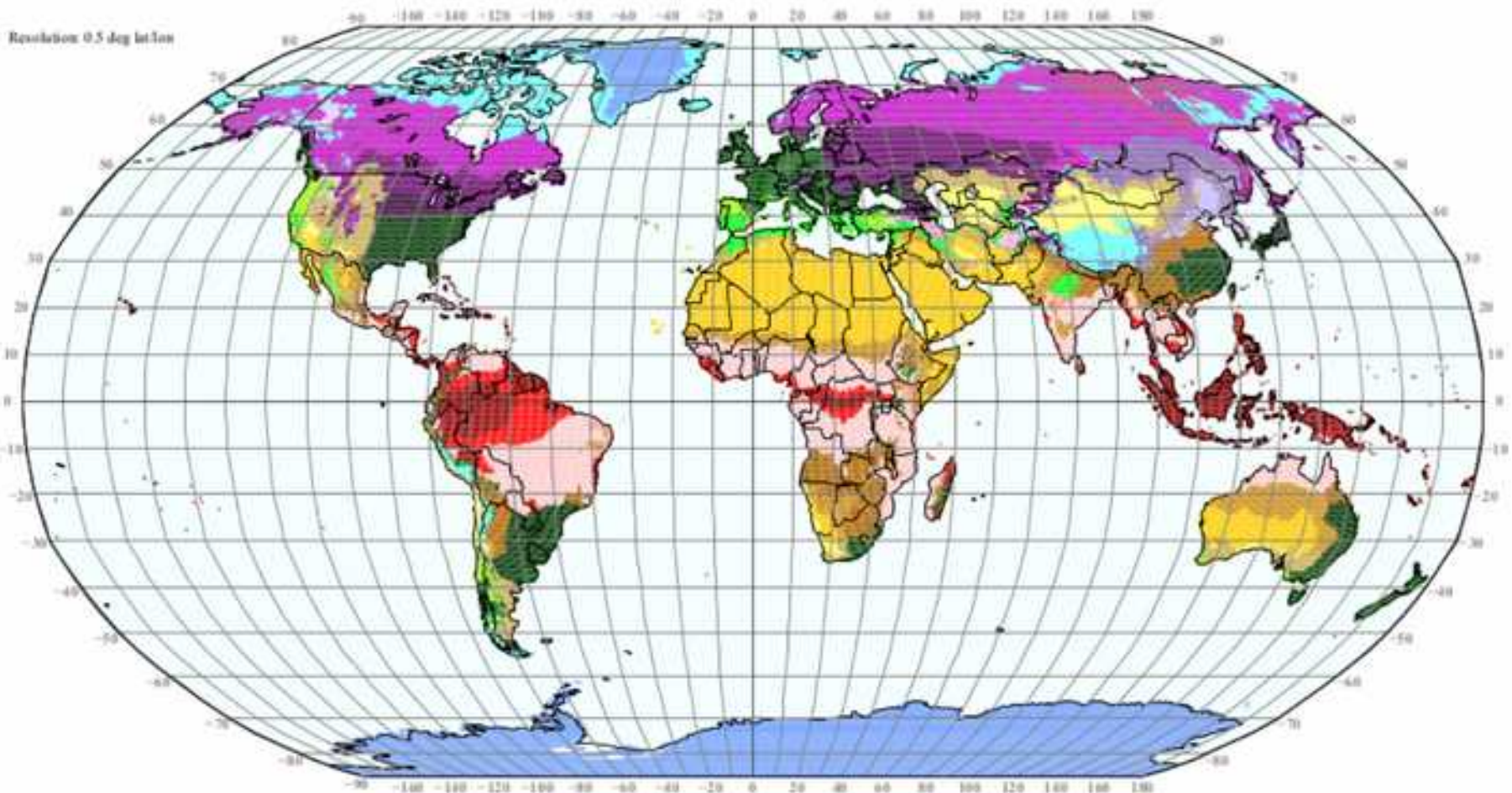
- A: equatorial
- B: arid
- C: warm temperate
- D: snow
- E: polar

Precipitation

- W: desert
- S: steppe
- f: fully humid
- a: summer dry
- w: winter dry
- m: monsoonal

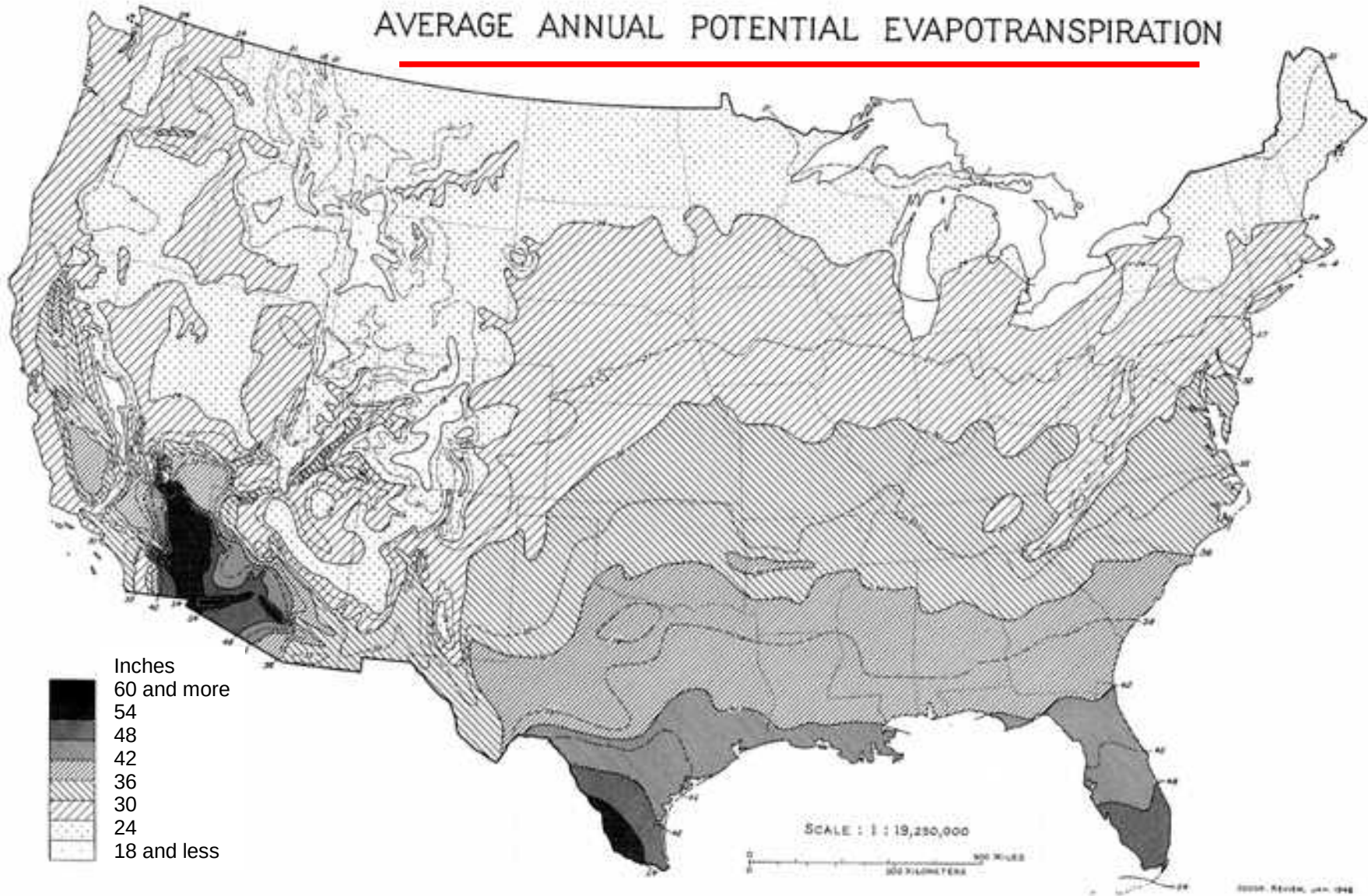
Temperature

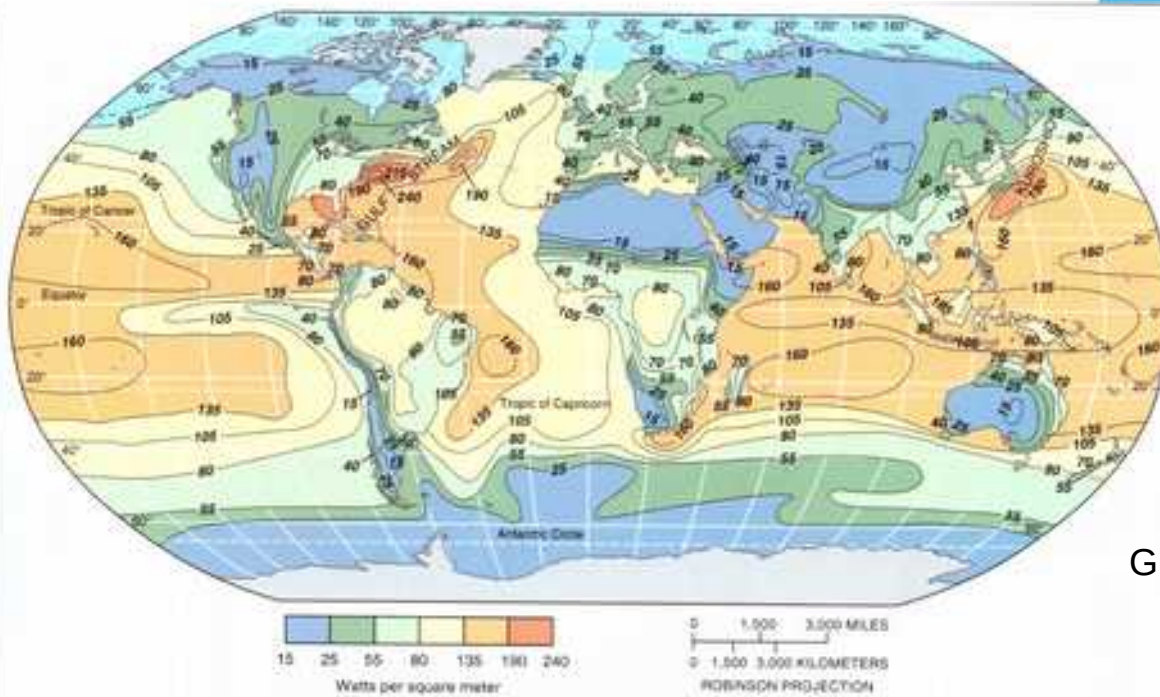
- h: hot arid
- k: cold arid
- a: hot summer
- b: warm summer
- c: cool summer
- d: extremely continental
- F: polar frost
- T: polar tundra



Climate classification

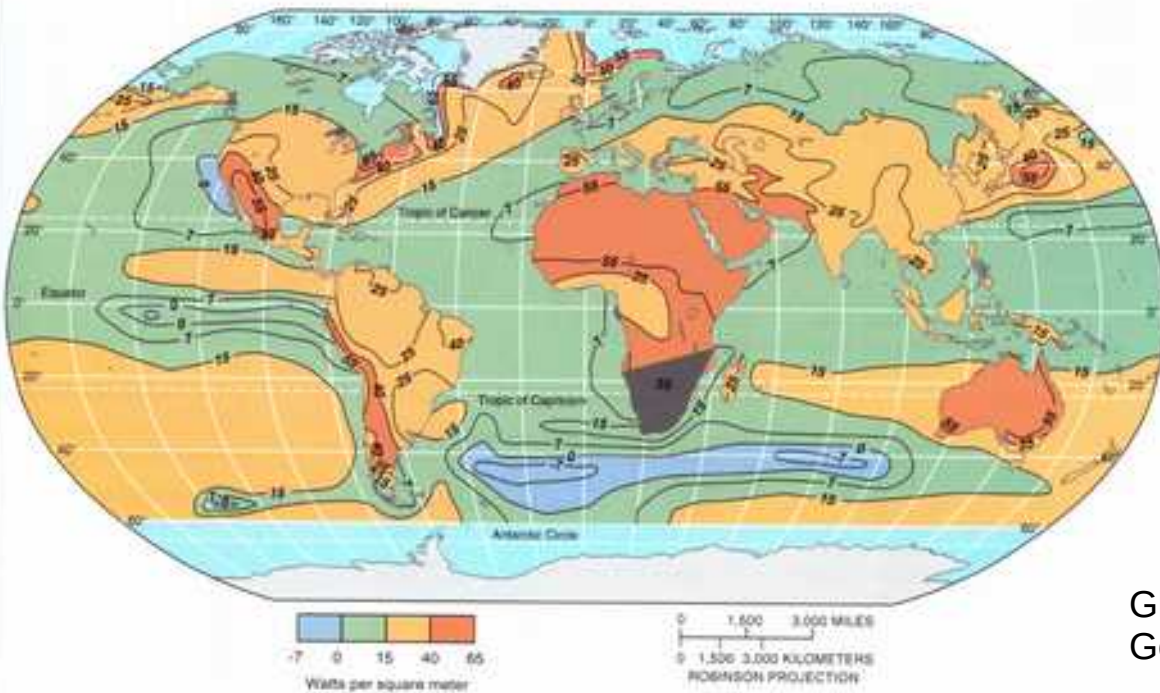
AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION





Genetic climate systems

Global heat of evaporation

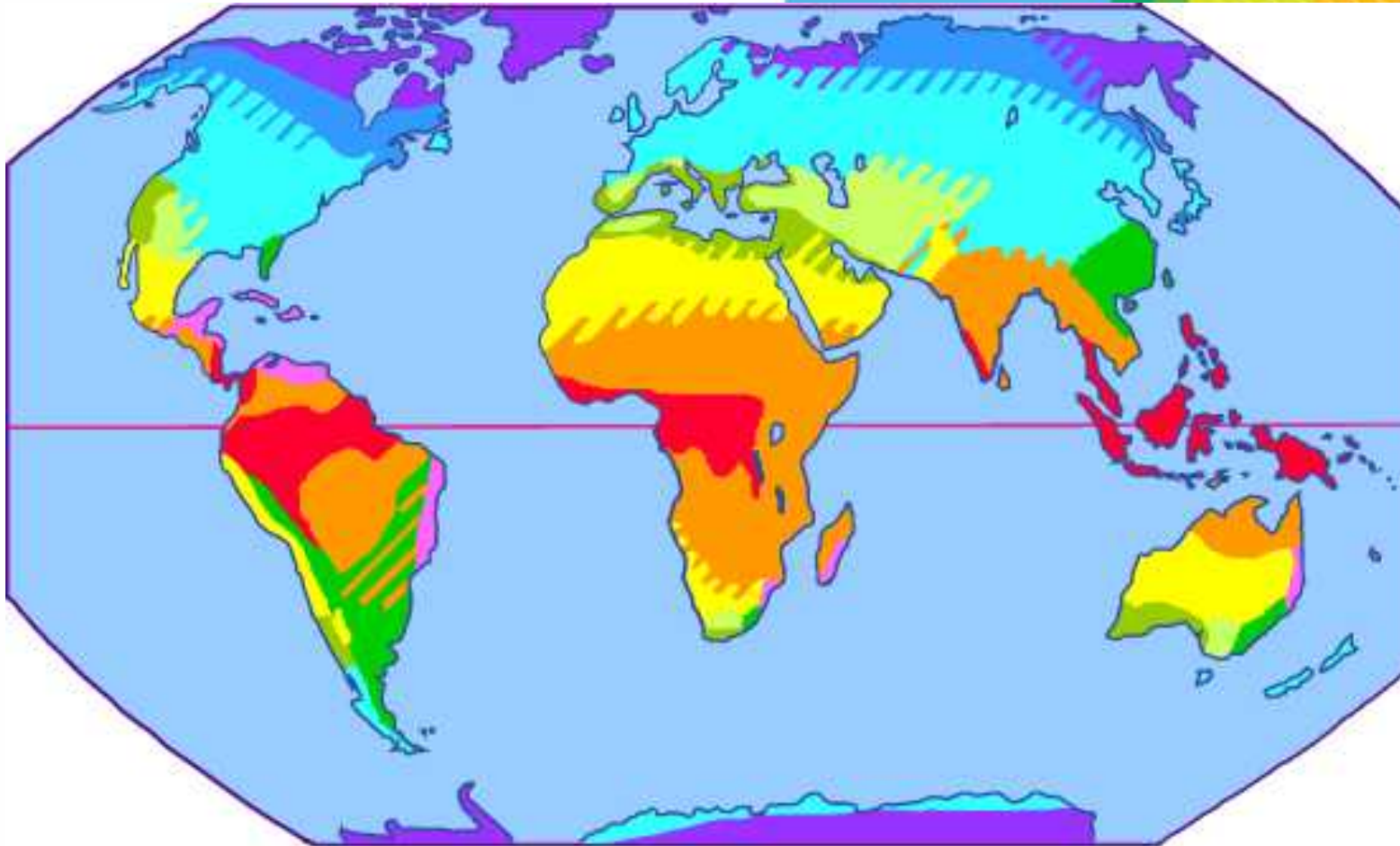


Global sensible heat (Christopherson R.W., Geosystems, 4e, 1999, Prentice Hall)



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Genetic climate systems

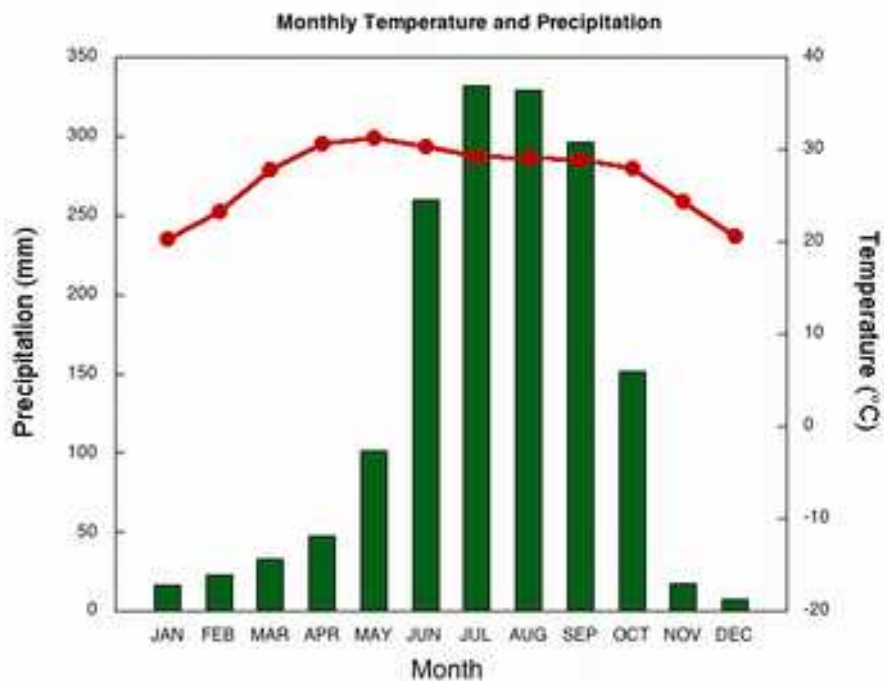
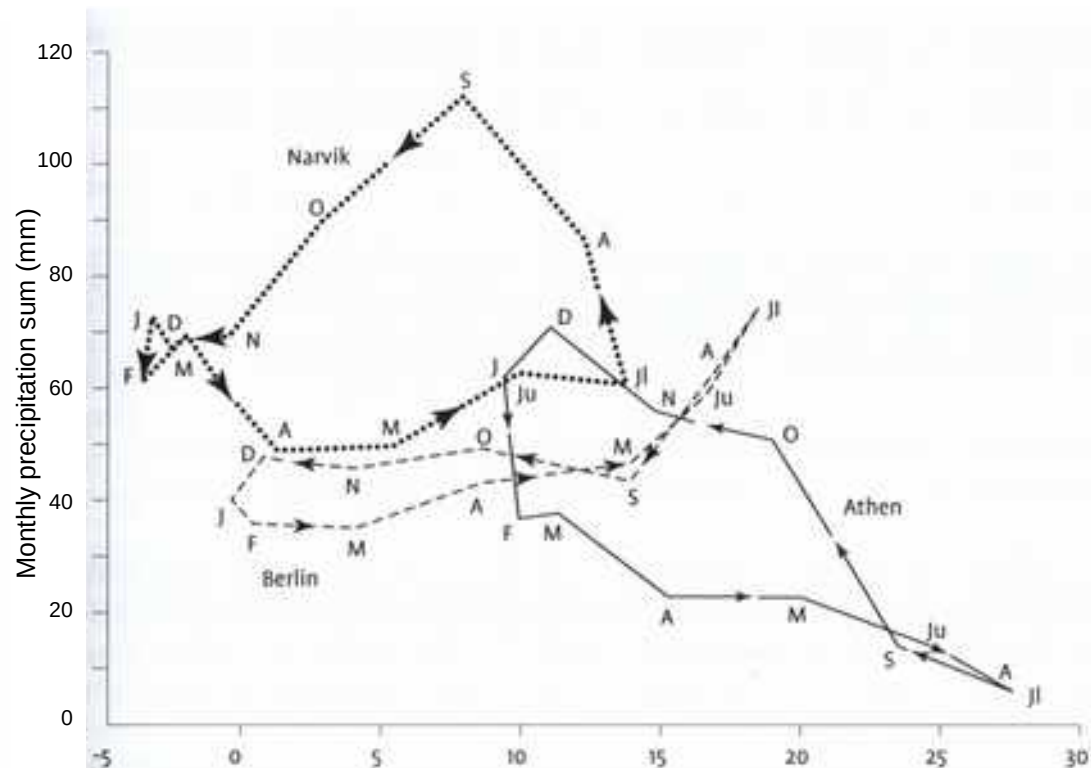


Flohn, 1950

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Climatological synopsis

Climatological diagrams



Monthly mean temperature (°C)

Index of continentality
 maritime/continental climate

.....

W. Gorczynski (1920): $K_G = 1.7 * (A_j / \sin\phi) - 20.4$



Climate data – **historic**, synoptic, re-analysed, satellite, radar

Wind - air temperature - air pressure

Meteorologiska Observationer vid Uleåborgs Fylkäs

i Januari månad år 1871

Vindarn.						Väderleden.			Yttre Thermometern.				Hygrometern.
U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	
U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	
1. St. blås	St. blås	St. blås	Mulet	St. blås	St. blås	-1	-1	-2					
2. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	-1	+1	-1					
3. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	+0	-1	+0					
4. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	-1	+1	-5					
5. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	-6	-5	-7					
6. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	-2	+1	-2					
7. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	-6	-9	-5					
8. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	9	10	10					
9. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	8	8	9					
10. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	16	16	16					
11. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	12	12	12					
12. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	13	13	13					
13. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	11	12	12					
14. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	16	15	11					
15. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	13	16	16					
16. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	16	12	11					
17. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	11	10	11					
18. St. blås	St. blås	St. blås	St. blås	St. blås	St. blås	13	13	14					

Barometern med dess Thermometern.						Vattenskipten.			Aviskningen.
U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	
U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	U. T. N.	
798.9	21.790.2	21.791.5	17						
799.9	21.792.2	21.793.5	21						
797.2	18.789.1	21.791.2	19						
792.9	17.792.2	19.793.0	20						
786.0	19.787.7	18.789.2	21						
782.2	18.787.5	16.781.5	18					Samtidigt v. drift	
781.8	18.787.2	17.782.9	17						
782.2	18.787.7	15.782.7	15						
787.2	18.789.0	21.795.2	20						
782.7	19.789.0	12.786.5	12						
786.2	18.786.0	16.786.0	17					fortfarande drift	
781.0	18.786.5	18.789.9	20						
779.2	19.786.0	15.786.5	20					Samtidigt v. drift	
779.2	18.789.1	15.789.5	21					fortfarande drift	
782.2	19.787.5	21.793.2	21						
792.8	18.789.7	10.789.0	17						
782.4	18.782.9	17.785.8	17						
788.5	16.787.9	15.786.2	12						



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Climate data – historic, **synoptic**, **re-analysed**, satellite, radar

Synoptic weather 'telegram' from every operational weather station in the world

```
IIiii or IIIII YYGGi 99LLL QLLLL  
ihVV Nddff 00fff 1sTTT 2sTTT 3PPPP 4PPPP 5appp 6RRRt 7wwWW  
8NCCC 9GGgg  
222Dv 0sTTT 1PPHH 2PPHH 3dddd 4PPHH 5PPHH 6IEER 70HHH 8aTTT  
333 0.... 1sTTT 2sTTT 3Ejjj 4Esss 5jjjj jjjjj 6RRRt 7RRRR  
8Nchh 9SSss
```

Code explanation: <https://en.wikipedia.org/wiki/SYNOP>

Vary sources also available over the internet.

No history!



Climate data – historic, synoptic, **re-analysed**, satellite, radar

Some sources of re-analysed
climatological data:

Name of the re-analysed data sets

NCEP / NCAR R1
NCEP / NCAR R2
MERRA
20th Century Reanalysis V2
20th Century Reanalysis V2c
FSR
WASWind
ERA Interim
U Delaware V3.01
CRU_TS 3.22
GHCN CAMS
GPCP V2
NOAA Rprecipitation Recon.
(Land)
HADSLP 2
HADISST
NOAAERSST
NOAAERSST V4
COBE
NASA NVAP
ERA 20C



Climate data – historic, synoptic, re-analysed, satellite, radar

The screenshot shows the 'ERA Interim, Daily' dataset selection page on the ECMWF website. The browser address bar shows the URL: `apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/`. The page title is 'ERA Interim, Daily'. The left sidebar contains navigation menus for 'Type of level' (with 'Surface' selected), 'ERA Interim Fields' (with 'Daily' selected), 'About', 'Navigation', and 'See also...'. The main content area is titled 'ERA Interim, Daily' and includes a note about the dataset's scope. Below this, there are two selection steps: 'Select date' with a date range from 1979-01-01 to 2015-12-31, and 'Select a list of months' which displays a grid of checkboxes for each month from 1979 to 2015. The grid has columns for months (Jan to Dec) and rows for years. At the bottom, there is a 'Select All or Clear' button.



Climate data – historic, synoptic, re-analysed, satellite, radar

ERA-Interim, Daily - IceWassel

www.drbs.fi

ERA-Interim, Daily

app.ecmwf.int/datasets/data/interim-full-daily/levtype=af/

Meistbesucht

Select time

00:00:00 06:00:00 12:00:00 18:00:00

Select All or Clear

Select step

0 3 6 9 12

Select All or Clear

Select parameter

- 2 metre deepport temperature
- 2 metre temperature
- 10 metre U wind component
- 10 metre V wind component
- 10 metre wind gust since previous post-processing
- 10 metre wind speed since previous post-processing
- Abatis
- Boundary layer thickness
- Boundary layer height
- Charnock
- Clear sky surface photosynthetically active radiation
- Convective available potential energy
- Convective precipitation
- Convective snowfall
- Downward W_v radiation at the surface
- Eastward gravity wave surface stress
- Eastward turbulent surface stress
- Evaporation
- Forecast albedo
- Forecast surface roughness
- Forecast surface roughness for heat
- Forecast surface roughness
- Gravity wave dissipation
- High cloud cover
- Ice temperature layer 1
- Ice temperature layer 2
- Ice temperature layer 3
- Ice temperature layer 4
- Interdecadal eastward turbulent surface stress
- Interdecadal moisture flux
- Interdecadal northward turbulent surface stress
- Interdecadal surface sensible heat flux
- Large-scale precipitation
- Large-scale precipitation fraction
- Large-scale snowfall
- Logarithm of surface roughness length for heat
- Low cloud cover
- Maximum temperature at 2 metres above previous post-processing
- Maximum temperature at 2 metres above previous post-processing
- Mean sea level pressure
- Mean wave direction
- Mean wave period
- Medium cloud cover
- Minimum temperature at 2 metres since previous post-processing
- Northward gravity wave surface stress
- Northward turbulent surface stress
- Aerosol
- Photosynthetically active radiation at the surface
- Sea surface temperature
- Significant height of combined wind waves and swell
- Skin temperature
- Skin temperature
- Snow albedo
- Snow density



Climate data – historic, synoptic, re-analysed, satellite, radar

ERA Interim, Daily - Iceweasel

File Bearbeiten Ansicht Chronik Lesenzeichen Extras Hilfe

www.drebs.fi ERA Interim, Daily

apps.ecmwf.int/datasets/data/interim-full-data/levtyper/mcf/ ERA-Interim daily

Meistbesucht

Surface net thermal radiation

- Surface pressure
- Surface sensible heat flux
- Surface thermal radiation downwards
- Temperature of snow layer
- Top net solar radiation, clear sky
- Top net thermal radiation, clear sky
- Total column ice water
- Total column ozone
- Total column water vapour
- Vertical integral of cloud frozen water
- Vertical integral of divergence of cloud frozen water flux
- Vertical integral of divergence of geopotential flux
- Vertical integral of divergence of mass flux
- Vertical integral of divergence of ozone flux
- Vertical integral of divergence of total energy flux
- Vertical integral of eastward cloud liquid water flux
- Vertical integral of eastward heat flux
- Vertical integral of eastward mass flux
- Vertical integral of eastward total energy flux
- Vertical integral of energy conversion
- Vertical integral of mass of atmosphere
- Vertical integral of northward cloud frozen water flux
- Vertical integral of northward geopotential flux
- Vertical integral of northward kinetic energy flux
- Vertical integral of northward ozone flux
- Vertical integral of northward water vapour flux
- Vertical integral of potential internal latent energy
- Vertical integral of temperature
- Vertical integral of total energy
- Volumetric soil water layer 1
- Volumetric soil water layer 3

Surface net thermal radiation, clear sky

- Surface roughness
- Surface solar radiation downwards
- Top scattered solar radiation
- Top net solar radiation
- Top net thermal radiation
- Total cloud cover
- Total column liquid water
- Total column water
- Total precipitation
- Vertical integral of cloud liquid water
- Vertical integral of divergence of cloud liquid water flux
- Vertical integral of divergence of kinetic energy flux
- Vertical integral of divergence of moisture flux
- Vertical integral of divergence of thermal energy flux
- Vertical integral of eastward cloud frozen water flux
- Vertical integral of eastward geopotential flux
- Vertical integral of eastward kinetic energy flux
- Vertical integral of eastward ozone flux
- Vertical integral of eastward water vapour flux
- Vertical integral of kinetic energy
- Vertical integral of mass tendency
- Vertical integral of northward cloud liquid water flux
- Vertical integral of northward heat flux
- Vertical integral of northward mass flux
- Vertical integral of northward total energy flux
- Vertical integral of ozone
- Vertical integral of potential internal latent energy
- Vertical integral of thermal energy
- Vertical integral of water vapour
- Volumetric soil water layer 2
- Volumetric soil water layer 4

Select All or Clear

View the MARS request Retrieve GRIB Retrieve NetCDF

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Climate data – historic, synoptic, **re-analysed**, satellite, radar

The screenshot shows a web browser window displaying the CECMWF website. The page is titled "Additional filtering" and contains a form for configuring a data request. The form fields are as follows:

- Stream: Atmosphere model
- Parameter: 2 metre temperature, Mean sea level pressure
- Dataset: intems_daily
- Area: 0
- Version: 1
- Type of Area: Surface
- Time: 00 00 00, 00 00 00, 12 00 00, 18 00 00
- Date: 19790101-16 19791231
- Type: Analysis
- Class: ERA-Interim

Below the form, it states: "The request will be done using the following attributes:"

- Area: Default (no area) [Change](#)
- Grid: 0.75x0.75 [Change](#)

At the bottom, there is a "Submit" button and a message: "No of rows".

The screenshot shows a web browser window displaying the CECMWF website. The page is titled "netcdf" and contains a request abstract. The abstract text is as follows:

Request abstract:
Atmosphere model, Surface, 1, intems_daily, 0.75x0.75, 2 metre temperature, Mean sea level pressure, 00 UTC 00 UTC 12 UTC 18 UTC, 1979-01-01...1979-12-31, Analysis, ERA-Interim

The status of the request is: **complete**

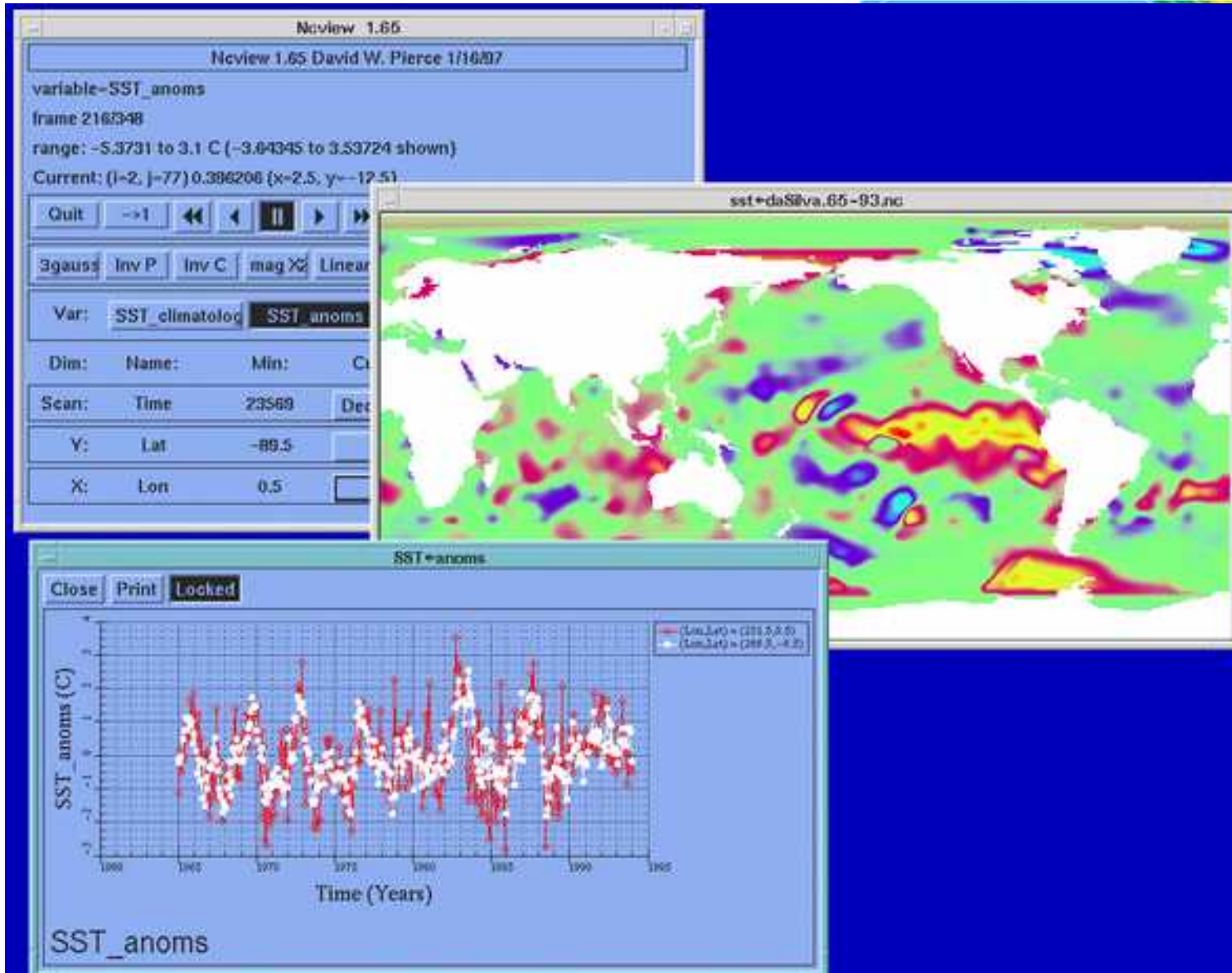
[Download \(644.3MB\)](#)

At the bottom, there is a message: "No of rows" and a copyright notice: "Copyright © ECMWF".



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Climate data – historic, synoptic, **re-analysed**, satellite, radar



Using the
Ncview - software



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Climate data – historic, synoptic, re-analysed, **satellite**, radar

Satellite Data Access by Dataset <https://www.ncdc.noaa.gov/data-access/satellite-data/satellite-data-access-datasets>

Satellite Data Access by Satellite and Instrument

<https://www.ncdc.noaa.gov/data-access/satellite-data/satellite-data-access-sorted-satellite-instrument>

Satellite Imagery <https://www.ncdc.noaa.gov/data-access/satellite-data/satellite-imagery>

Satellite Datasets in Development <https://www.ncdc.noaa.gov/data-access/satellite-data/satellite-datasets-development>



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Open climate data sources

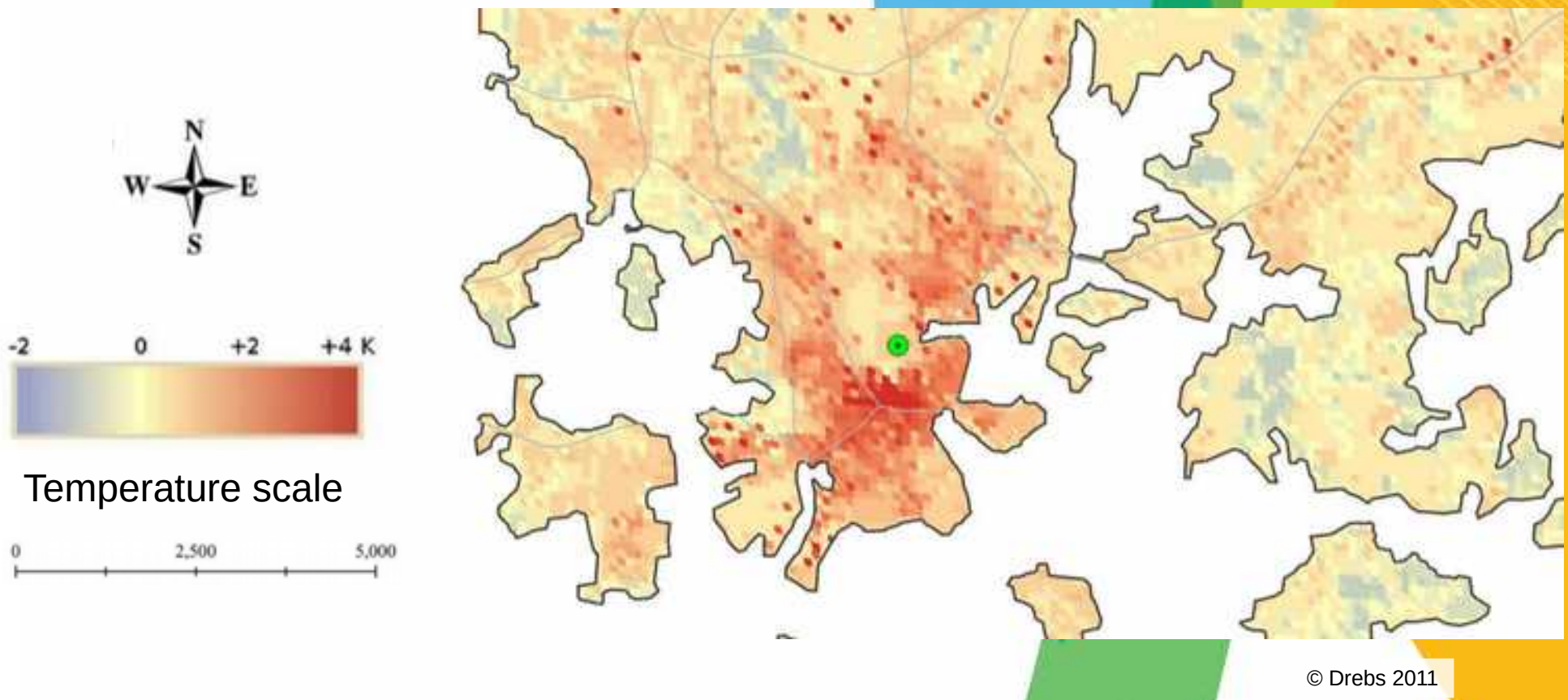
Open data by the FMI
Weather and climate observations
Weather radar and lightning observation
Real-time observation, air temperature, humidity,
air pressure, wind, in 10 minutes frequency





Climatological applications – Urban Climate

The urban heat island of city centre Helsinki





Climatological applications – Urban / Human Climate

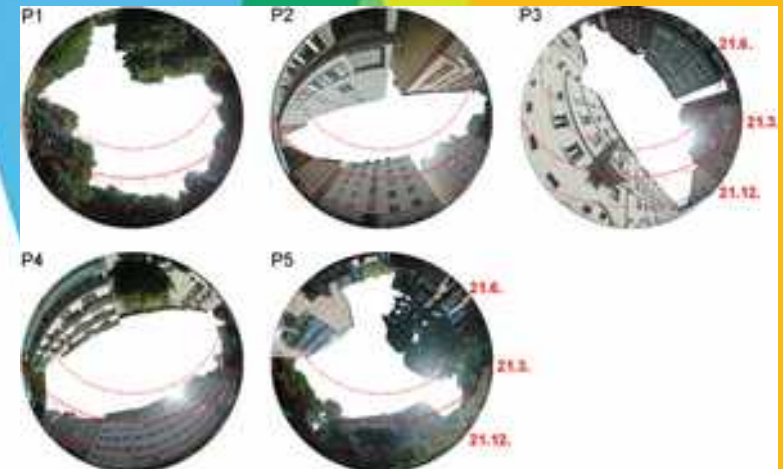


Green wall

Green roof



Human comfort

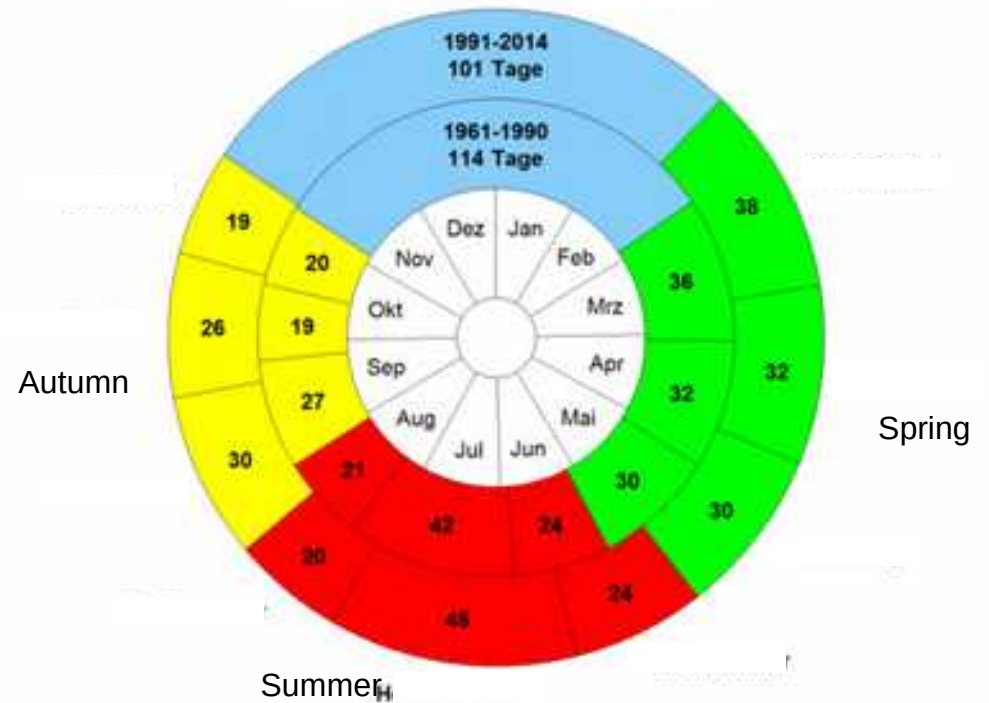
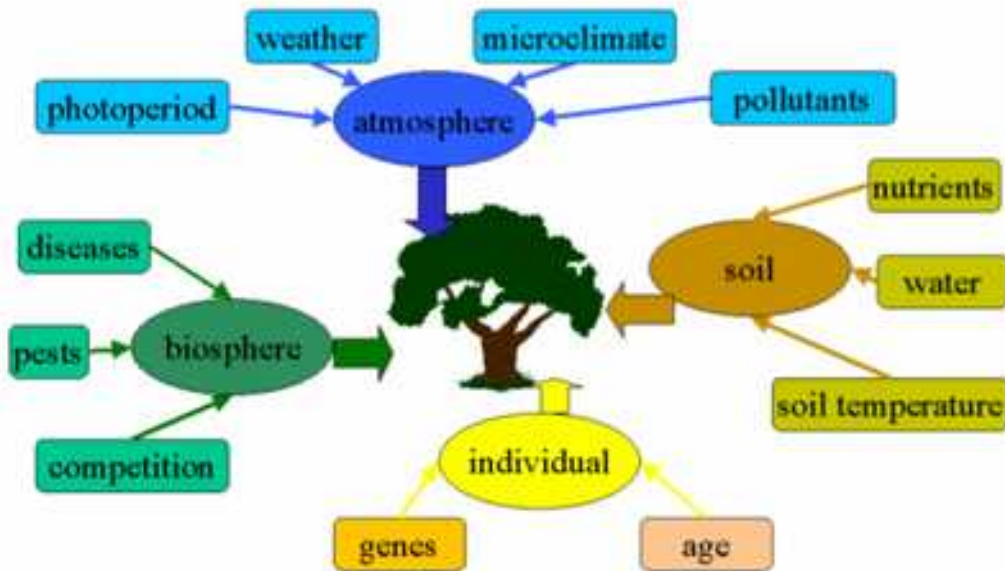


Fish-eye photos of the chosen locations in Stuttgart-West, Ketterer & Matzarakis 2014

Climatological applications – Phenology

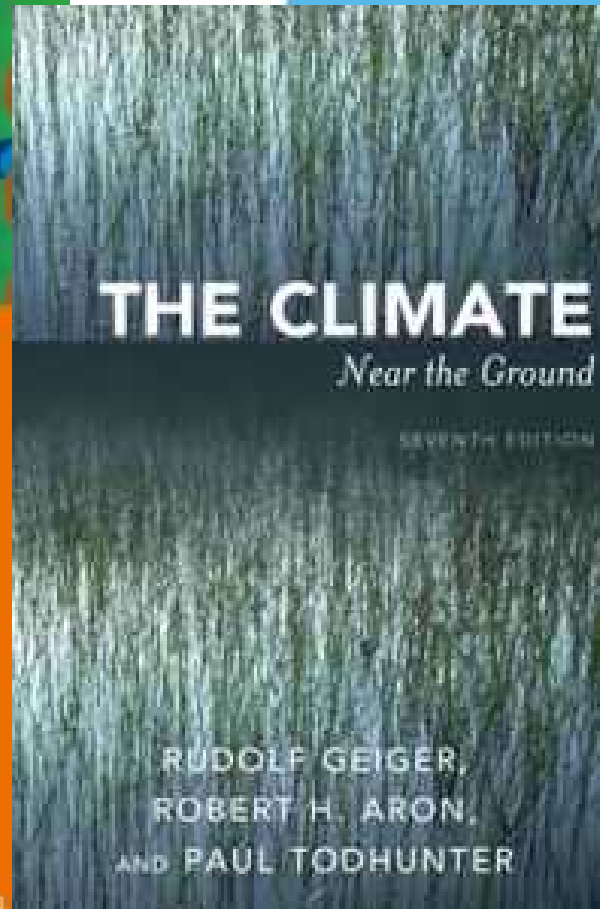


Phenological clock for Rhineland-Palatinate





2013
660 pages



2009
642 pages



1987
464 pages

Literature

... and all kind of books about general climatology