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Climate science, methods and data

Achim Drebs

Senior scientist

Finnish Meteorological Institute

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

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Content

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About climatological scales in time and space

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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

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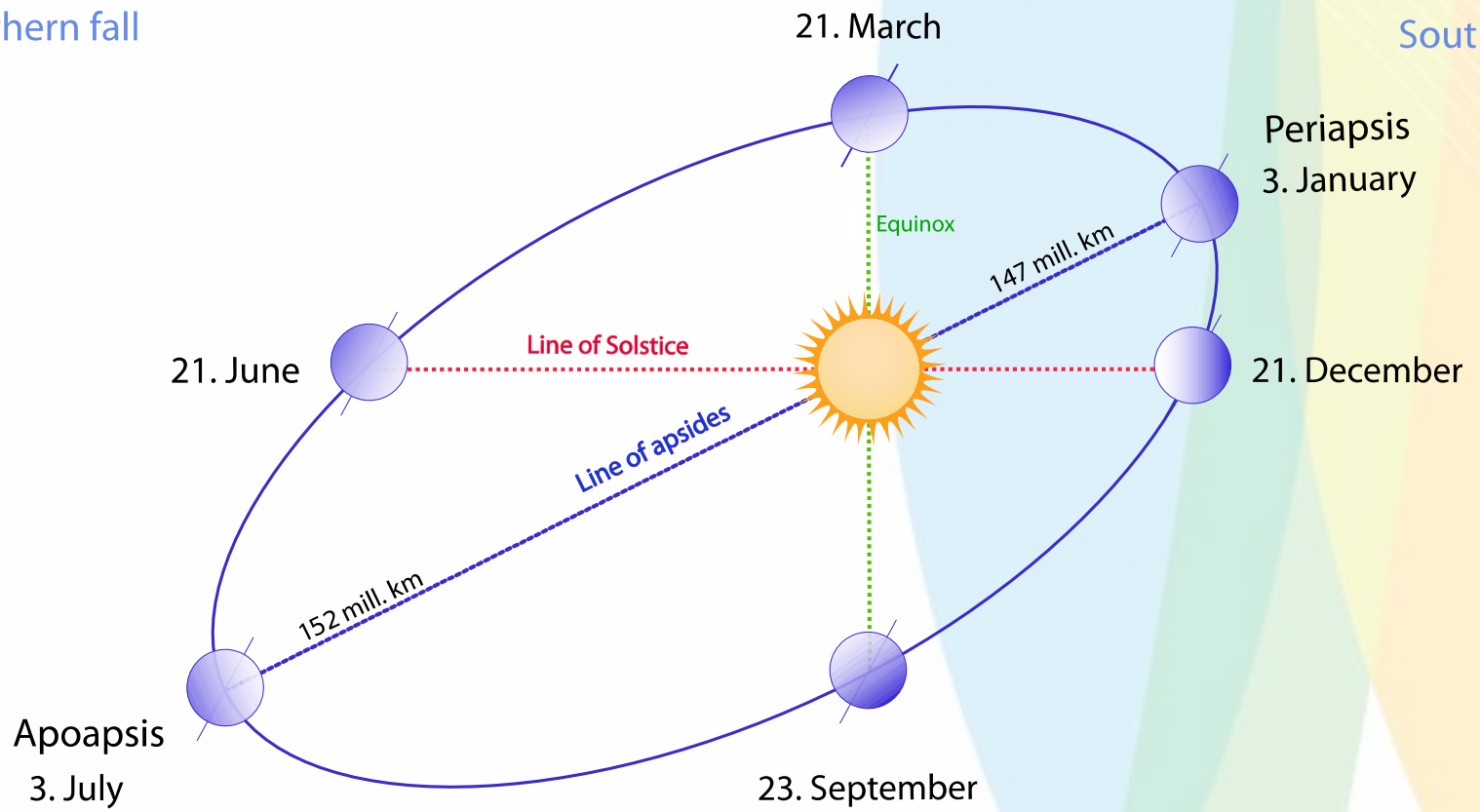
Lines of Solstice, apsides, Equinox

Northern spring/
Southern fall

Northern winter/
Southern summer



Northern summer/
Southern winter

Northern fall/
Southern spring

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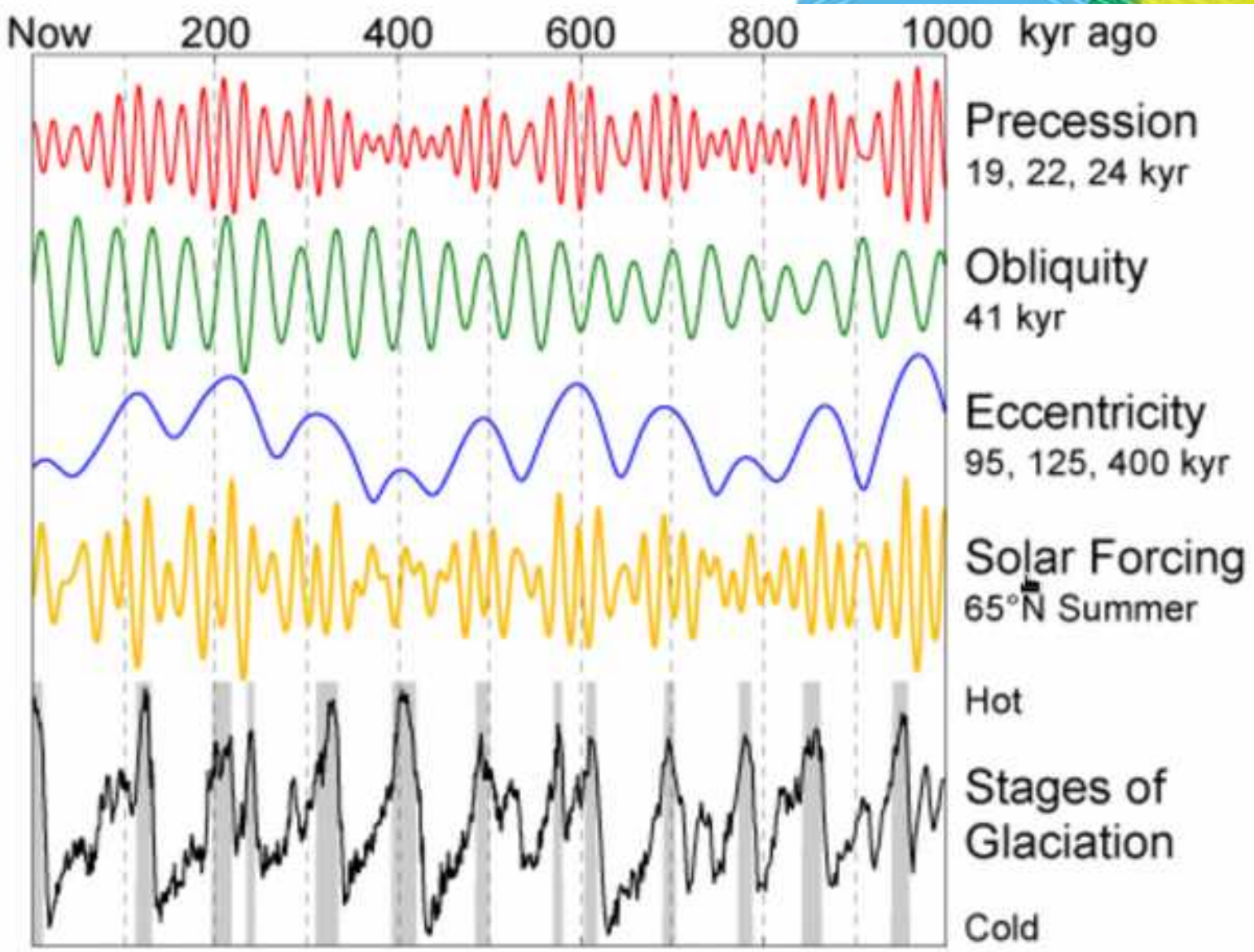
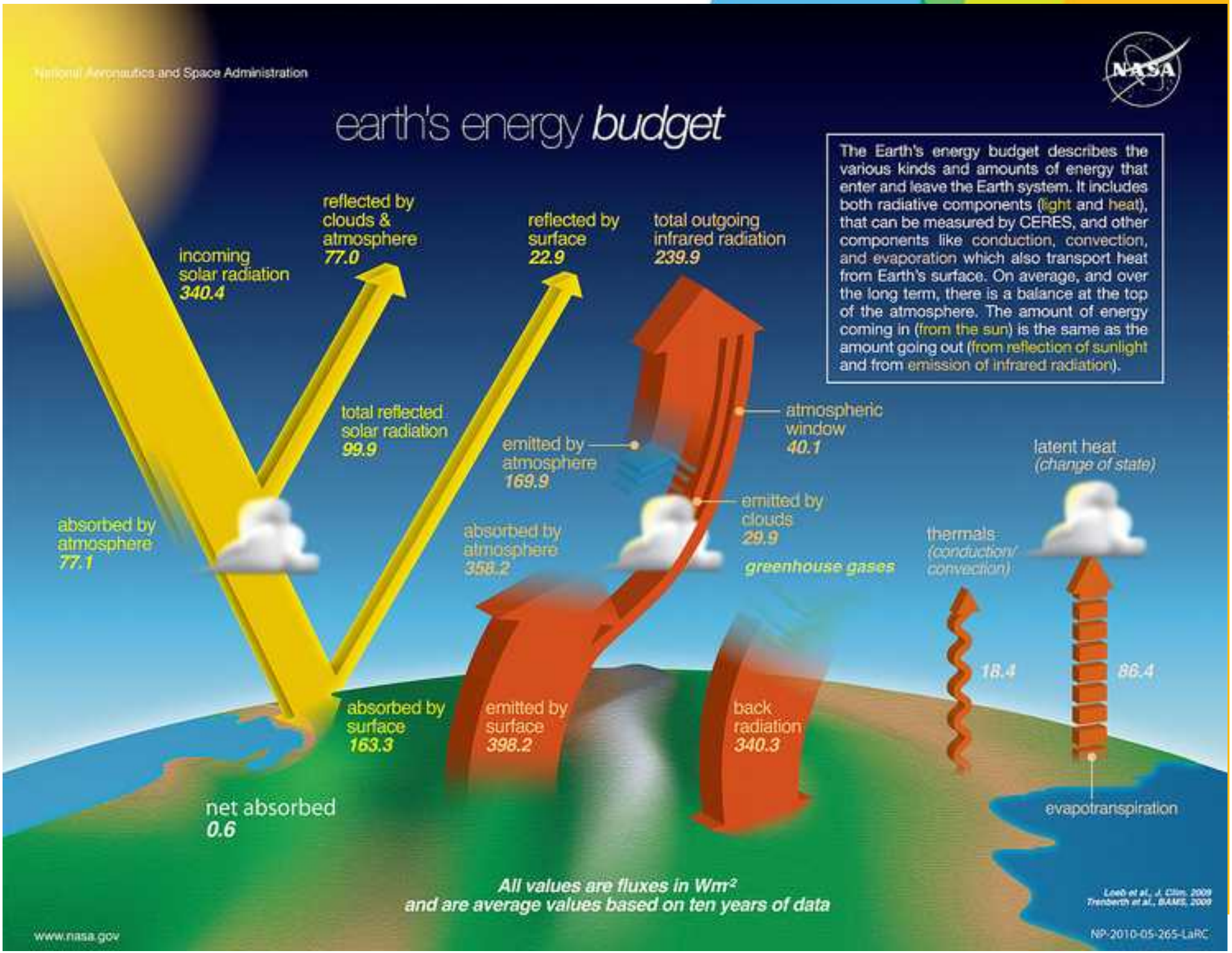
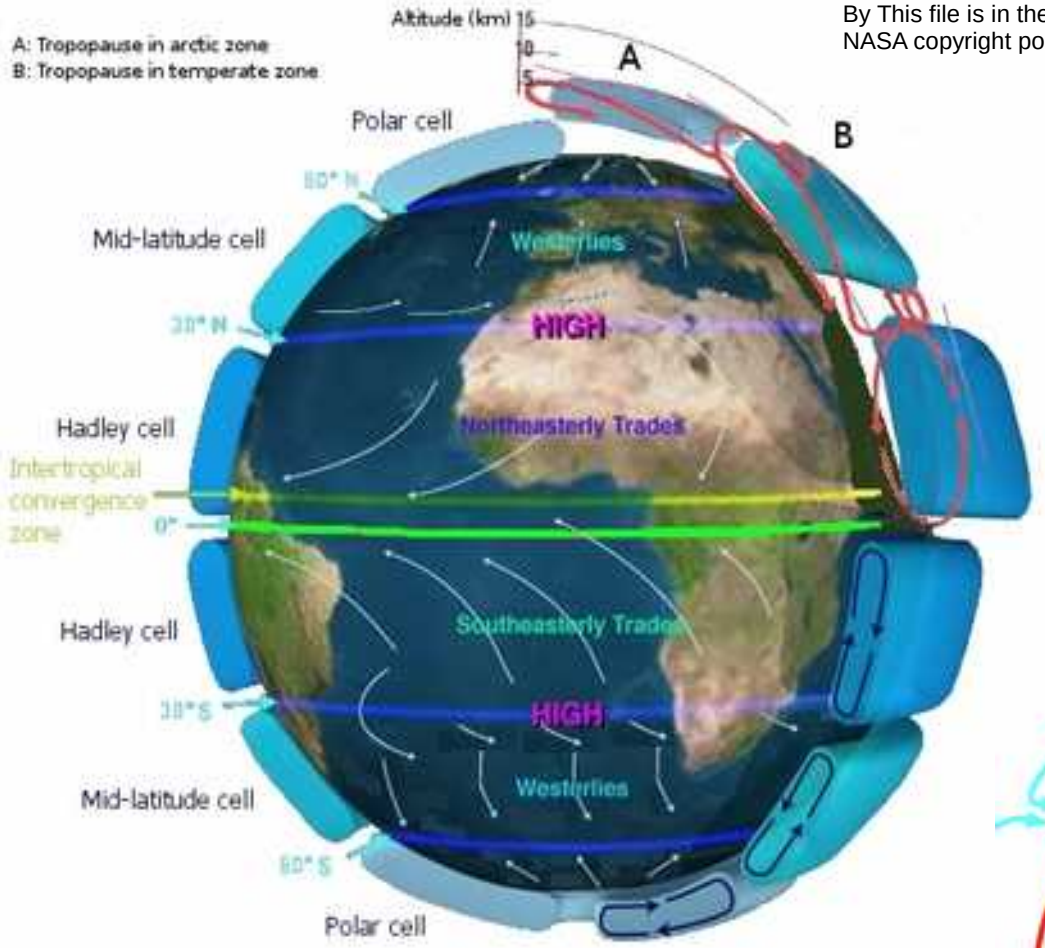
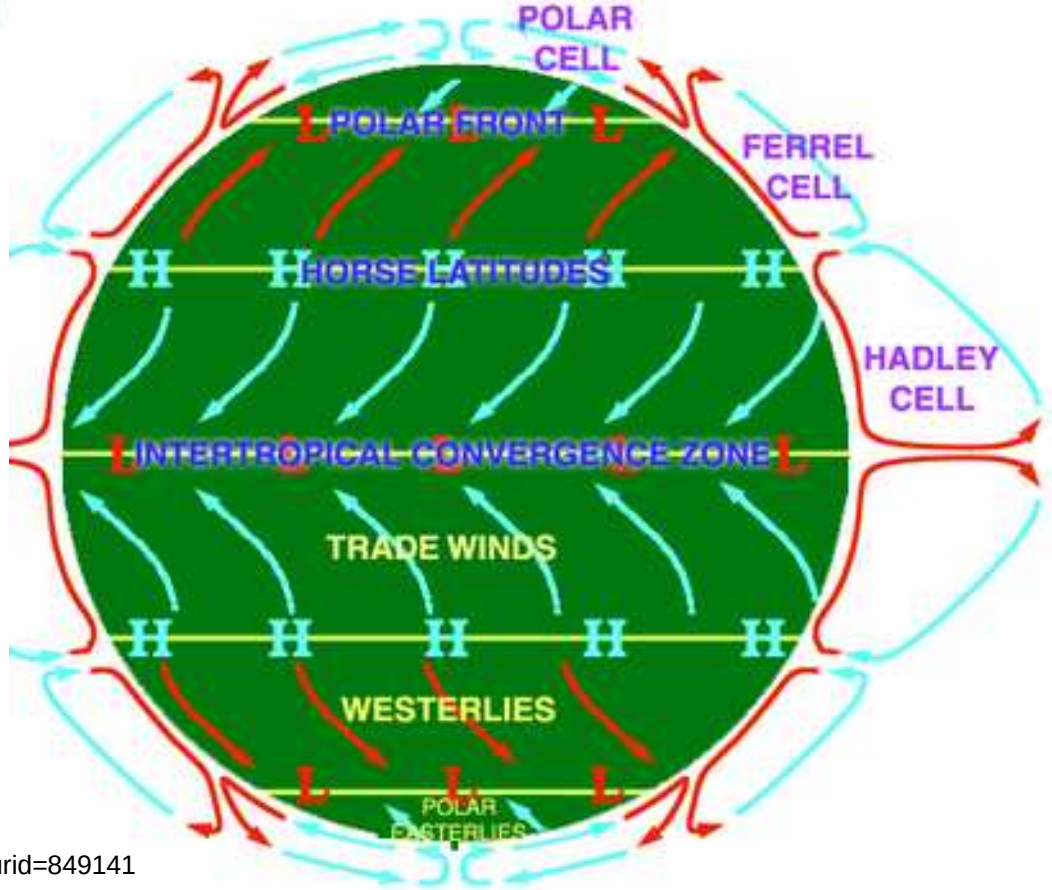
Milankovitch cycles



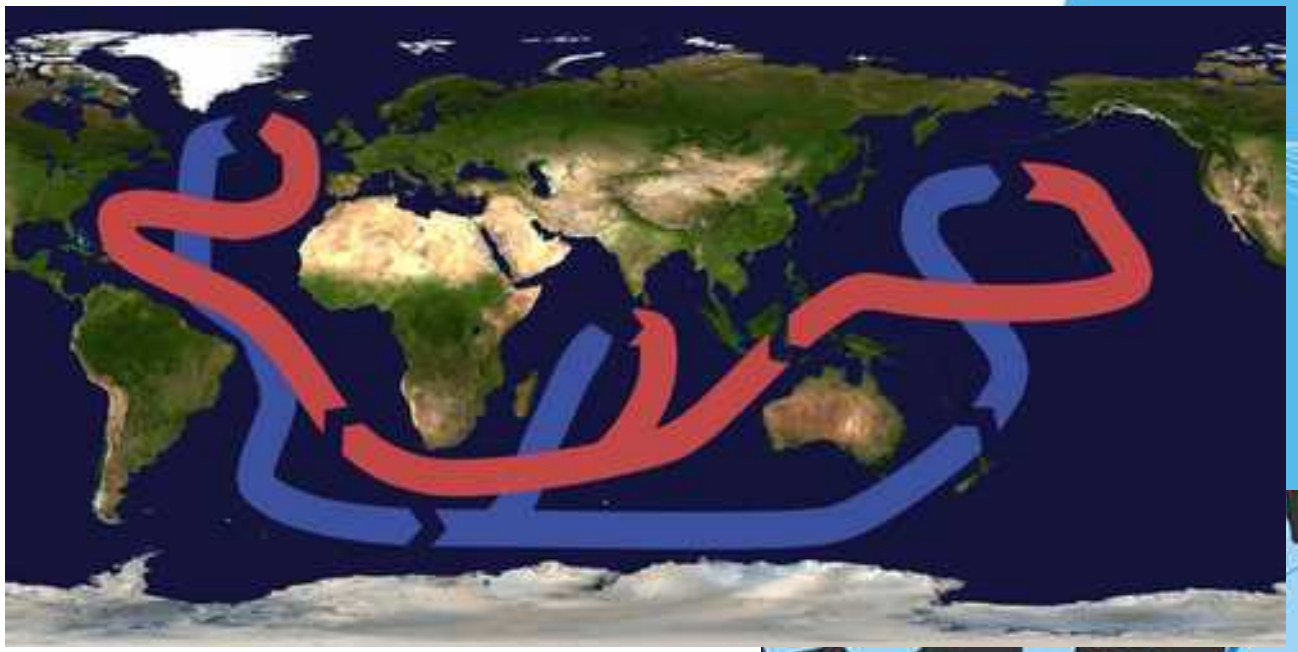




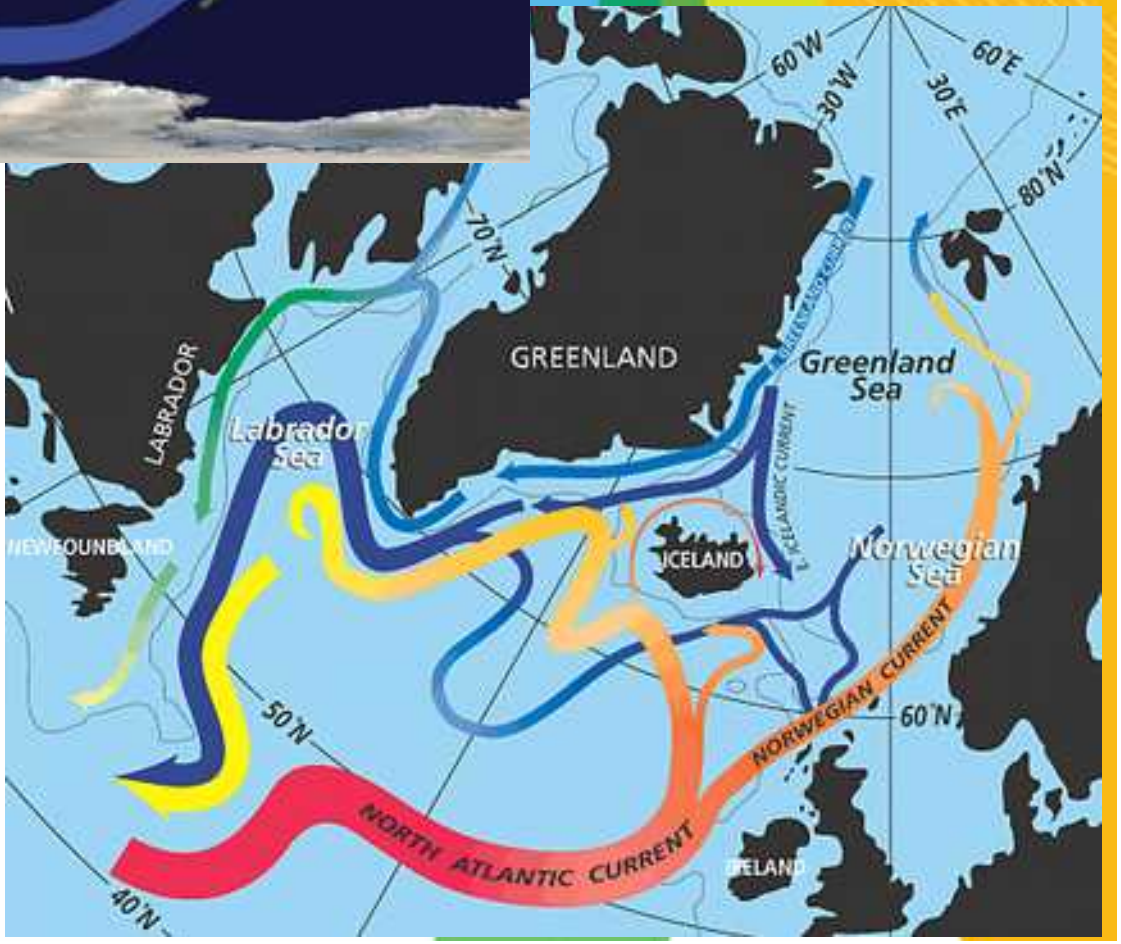
Atmospheric wind circulation



About 150 local wind systems



Earth's ocean circulation



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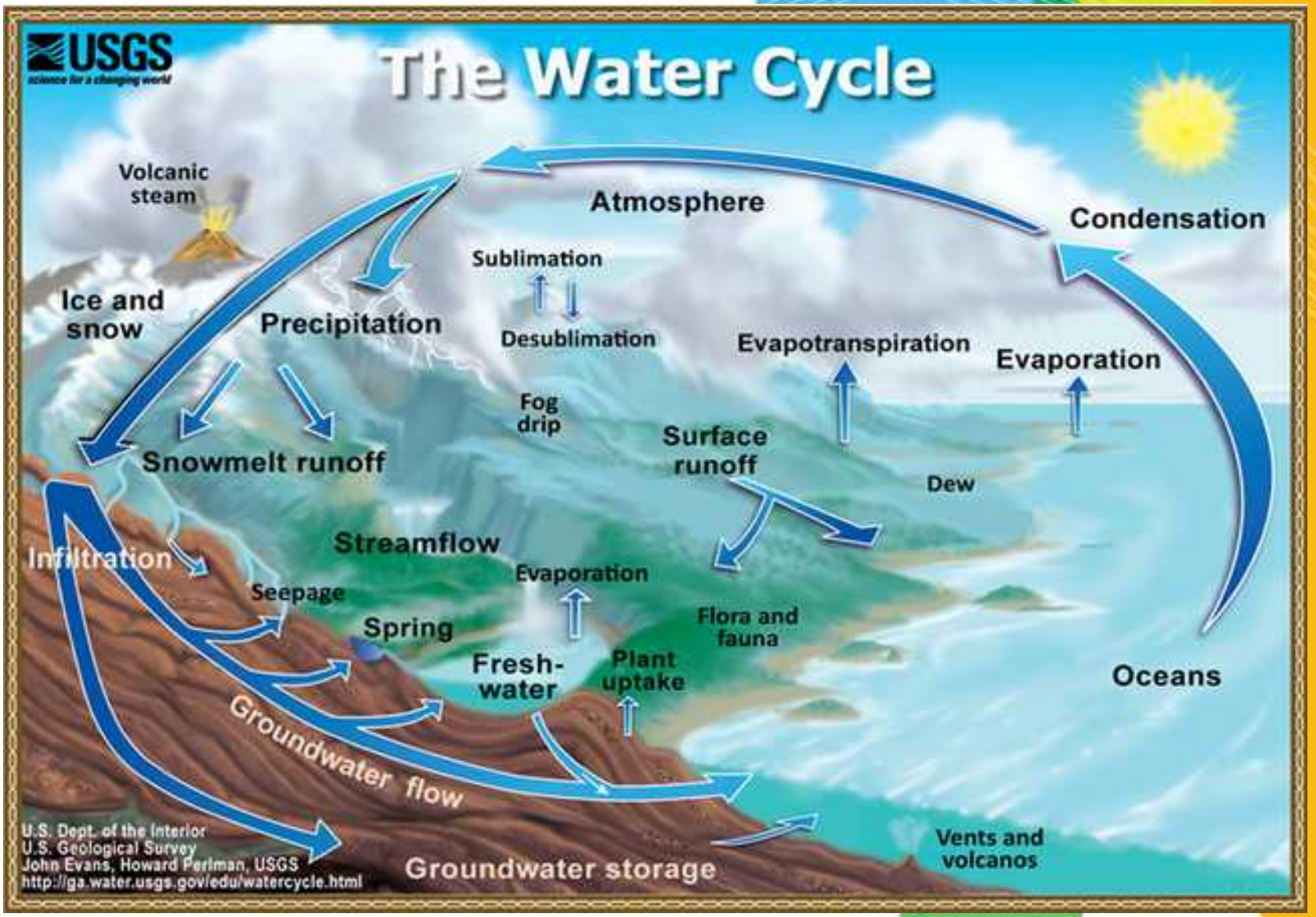
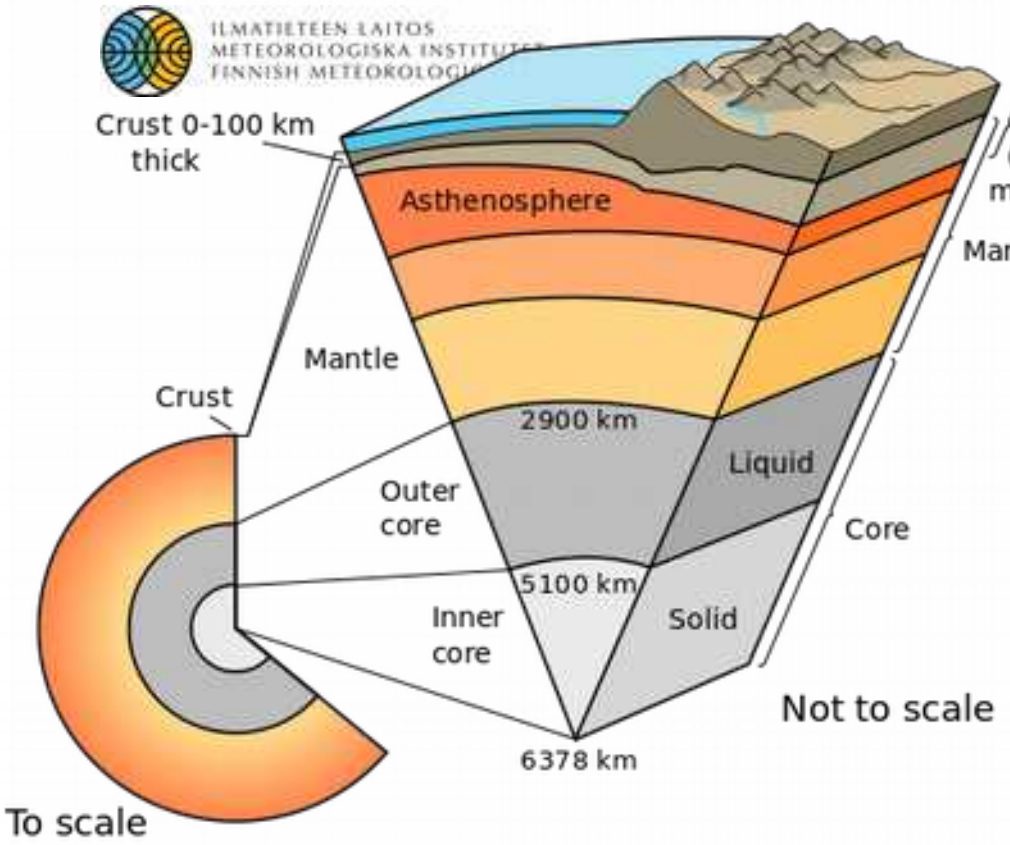
Hydrosphere



Cryosphere

Lithosphere



Biosphere

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About climatological scales in time and space

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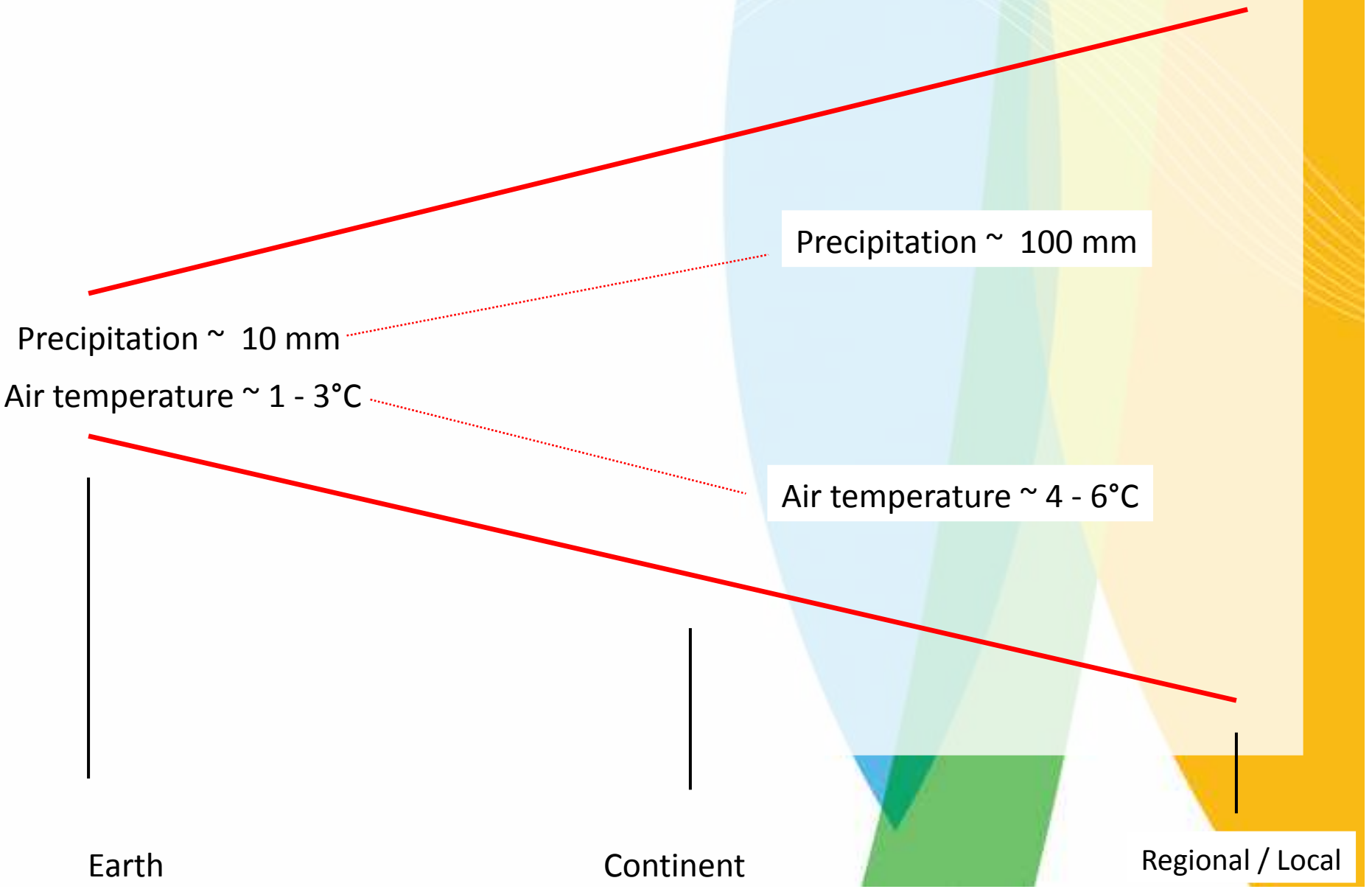
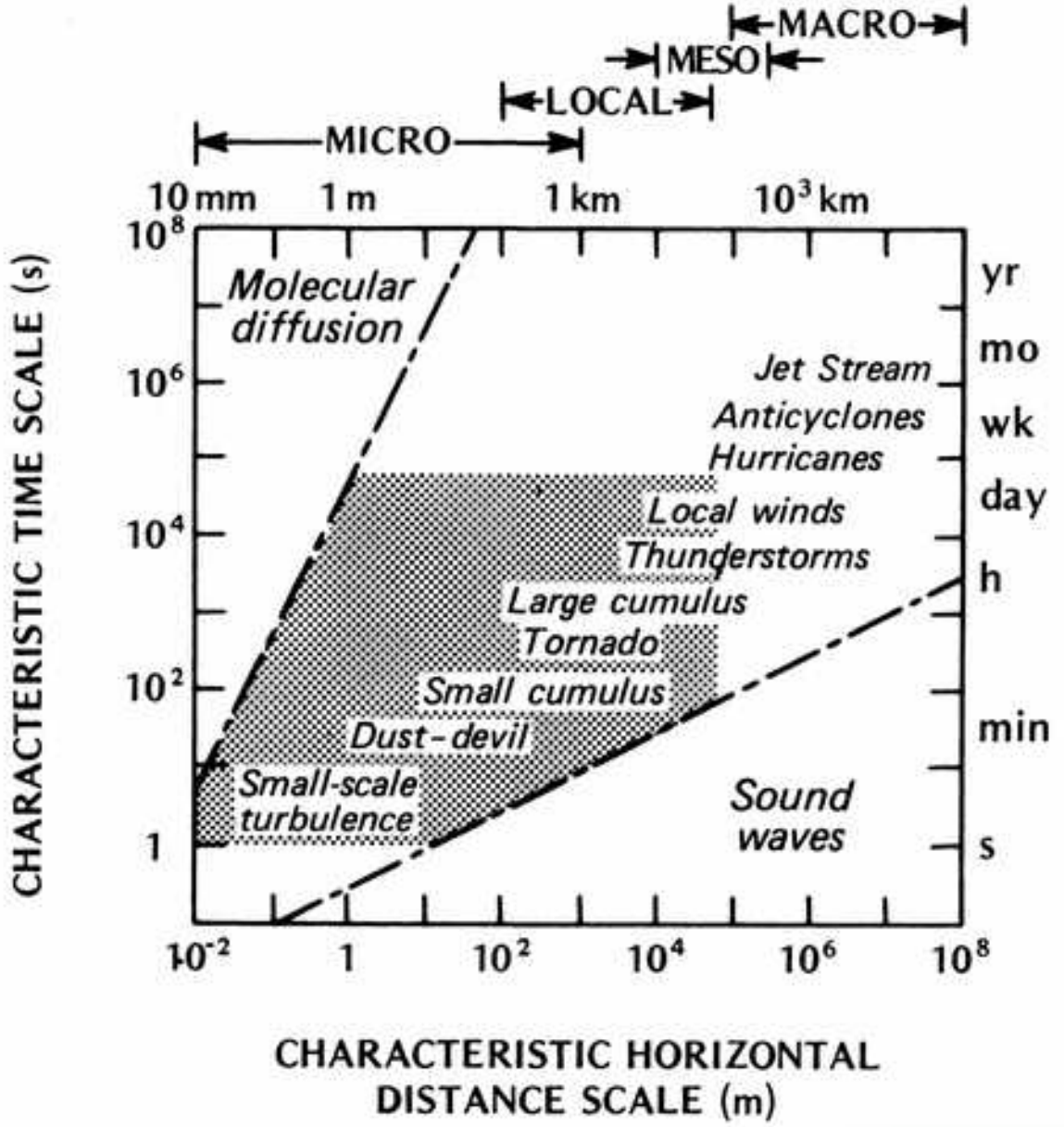
About scaling …





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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

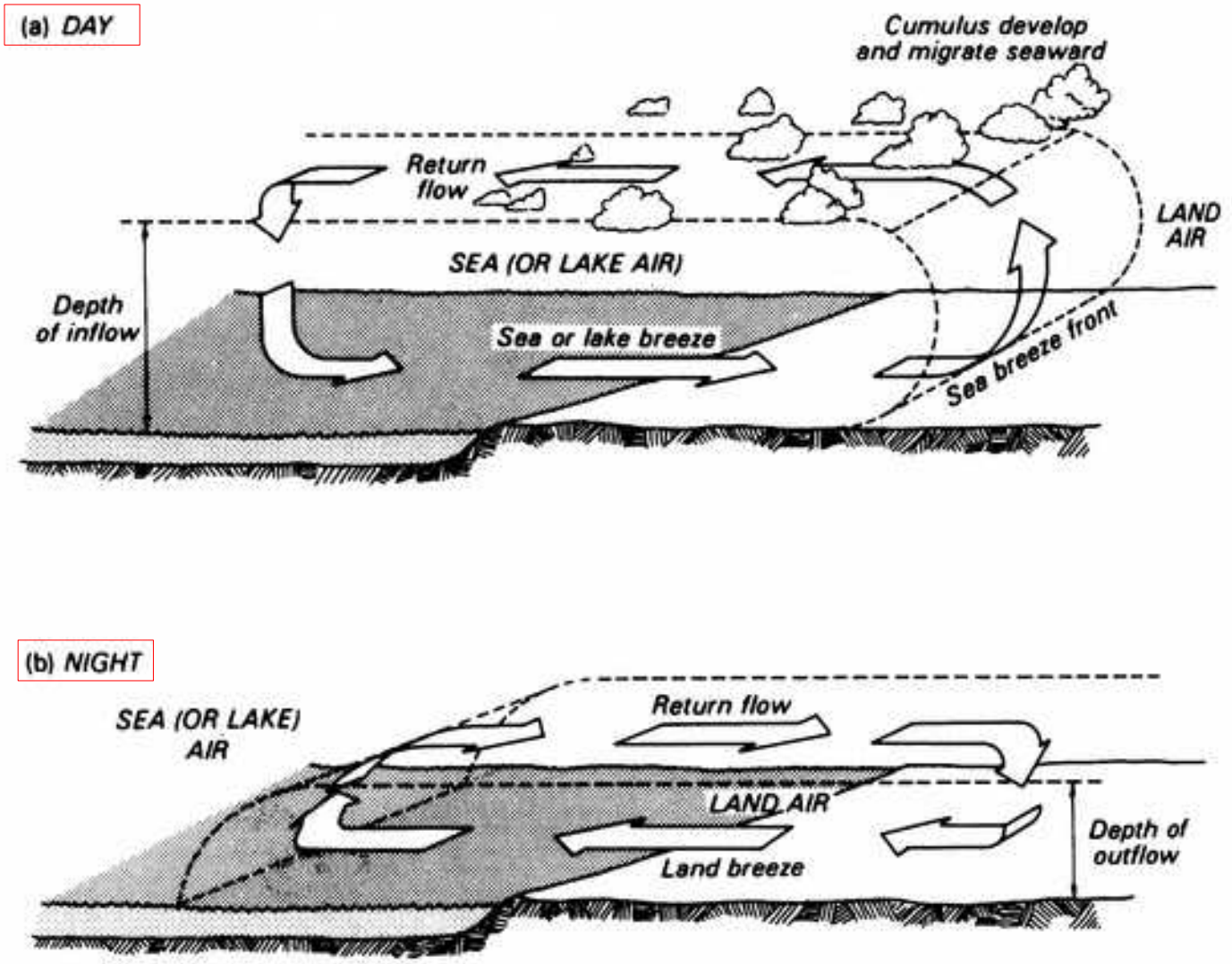
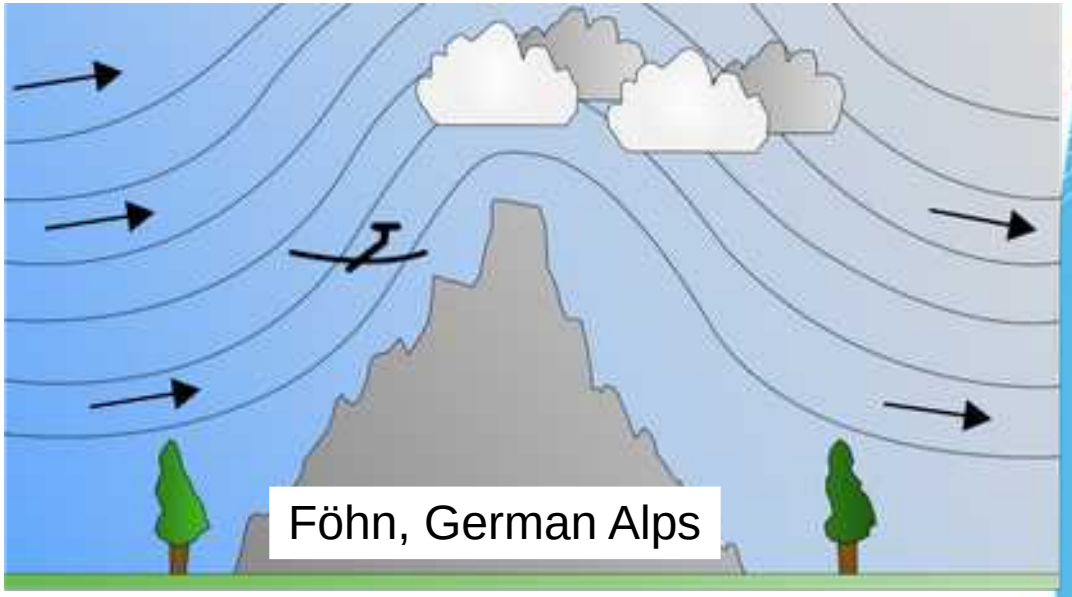
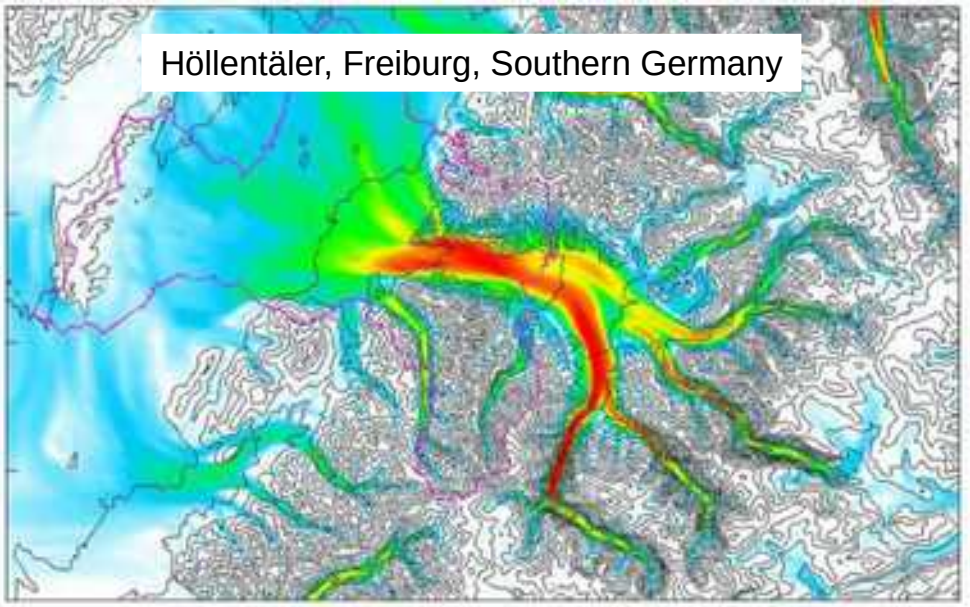


Figure 5.6 Land and sea (lake) breeze circulations across a shoreline (a) by day and (b) at night, during anticyclonic weather.

Local wind systems



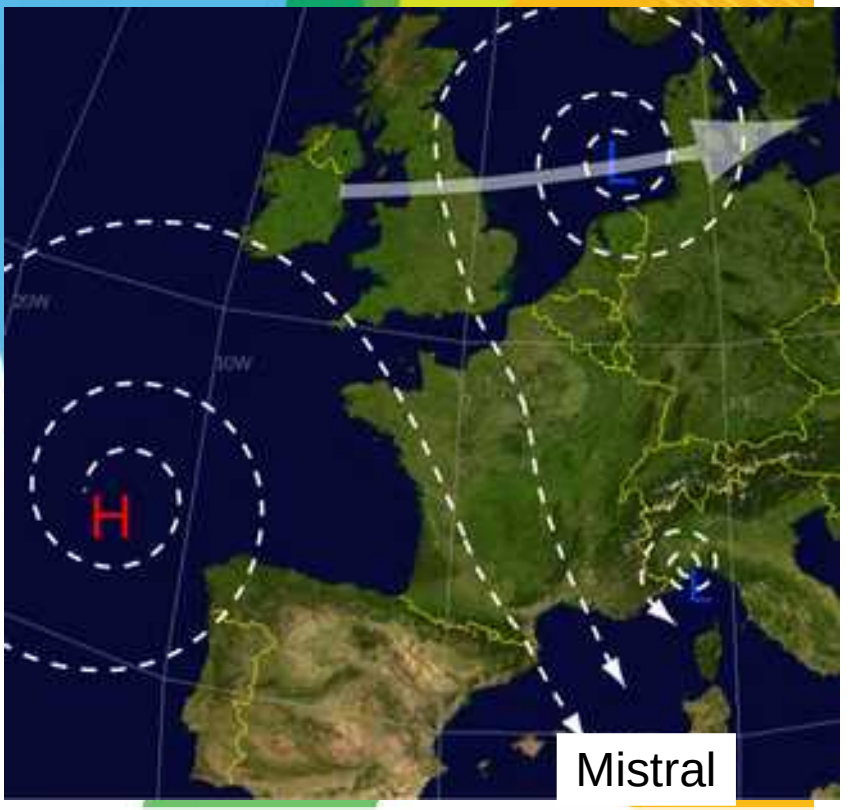
Föhn, German Alps



Höllentäler, Freiburg, Southern Germany

Air flow in m³/s

0 100 200 300 400 500



Mistral

dry, cold, strong wind that occurs in Southern France

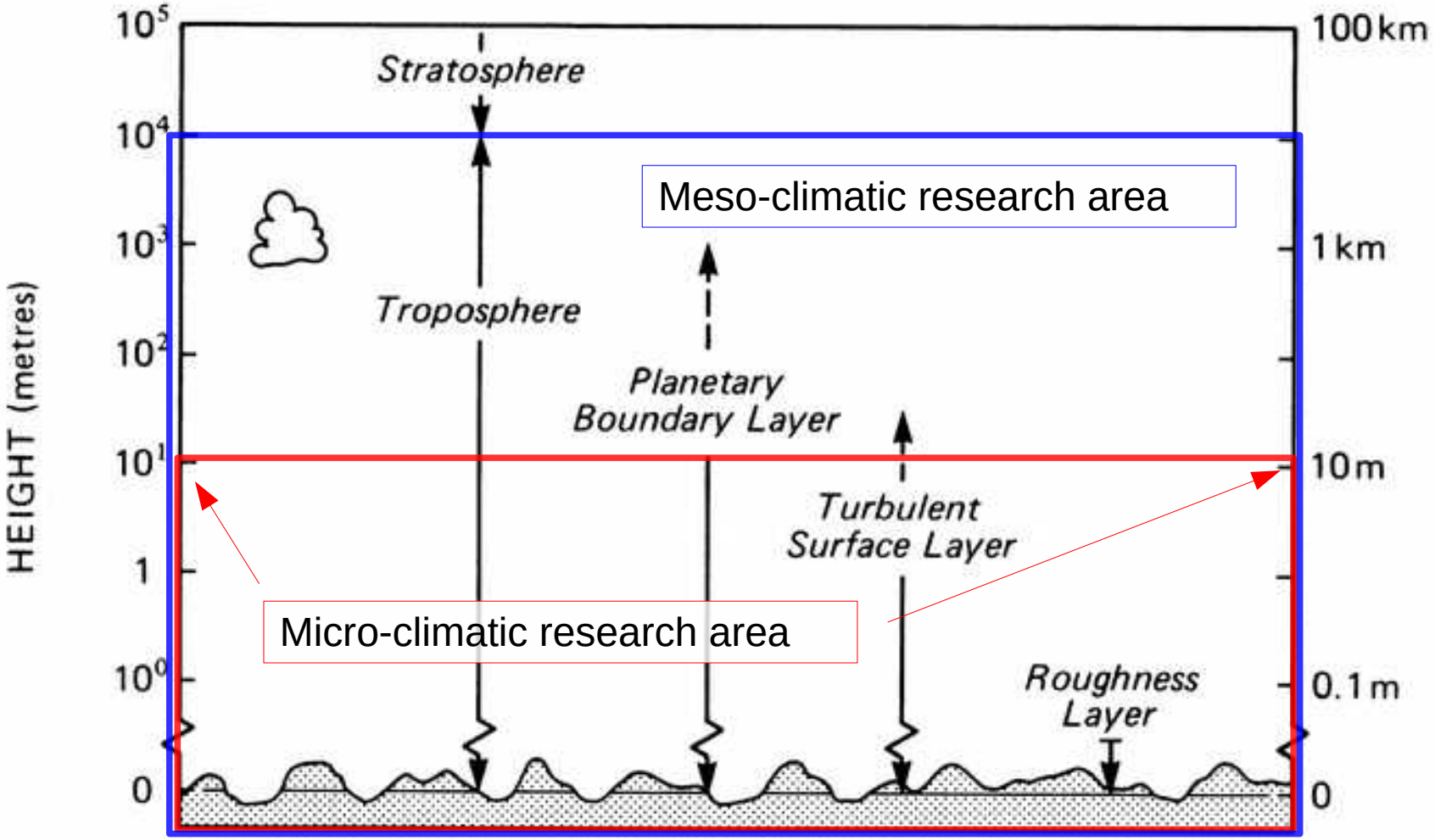


Figure 1.2 The vertical structure of the atmosphere.

34 °C

5 °C

depth

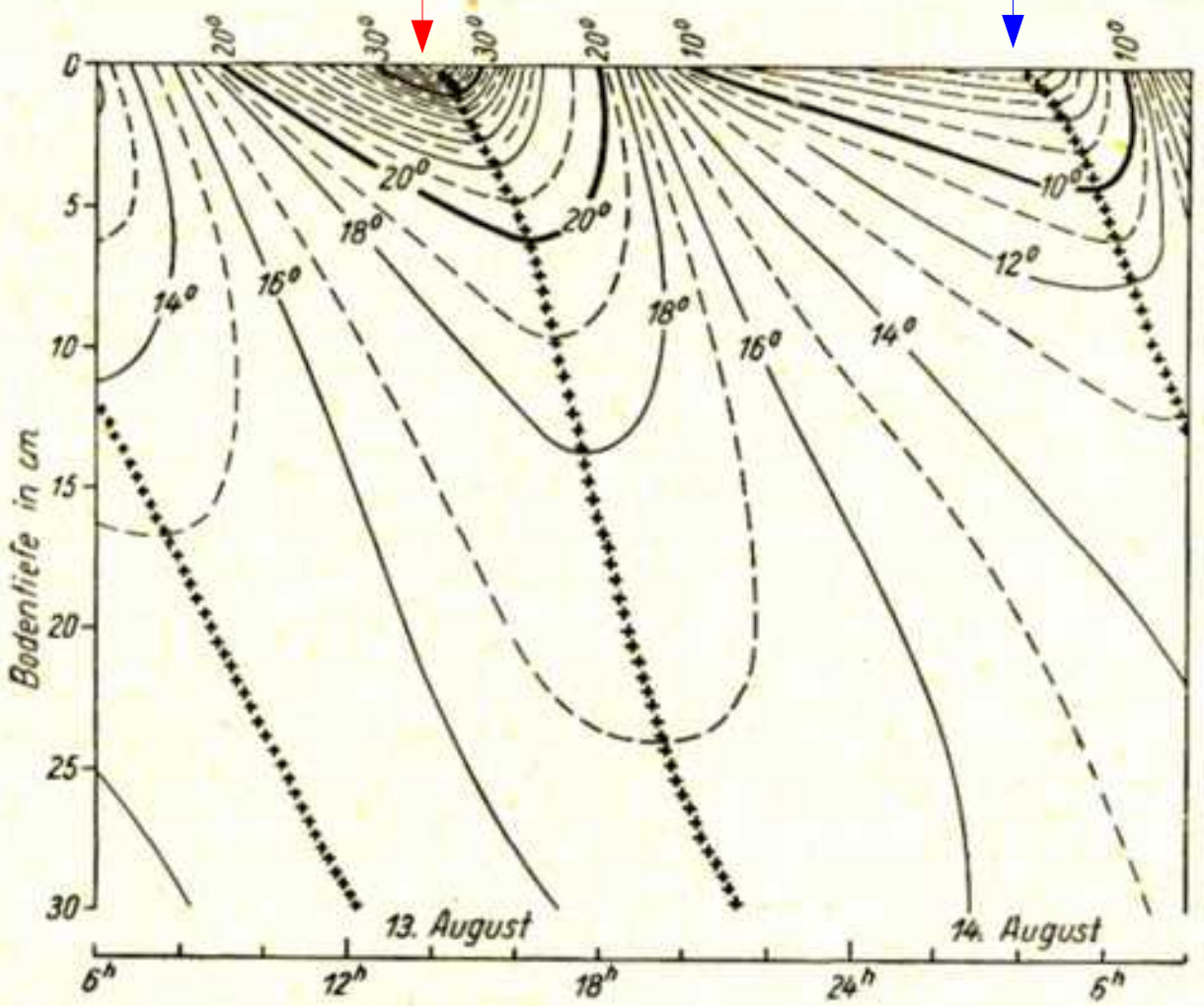


Abb. 20. Eindringen der täglichen Wärmewelle in den Boden an einen ungestörten Sommertag (nach Beobachtungen von *Th. Homén* in Finnland)

Soil temperature in Karjalohja, Finland, August 1893, Homén

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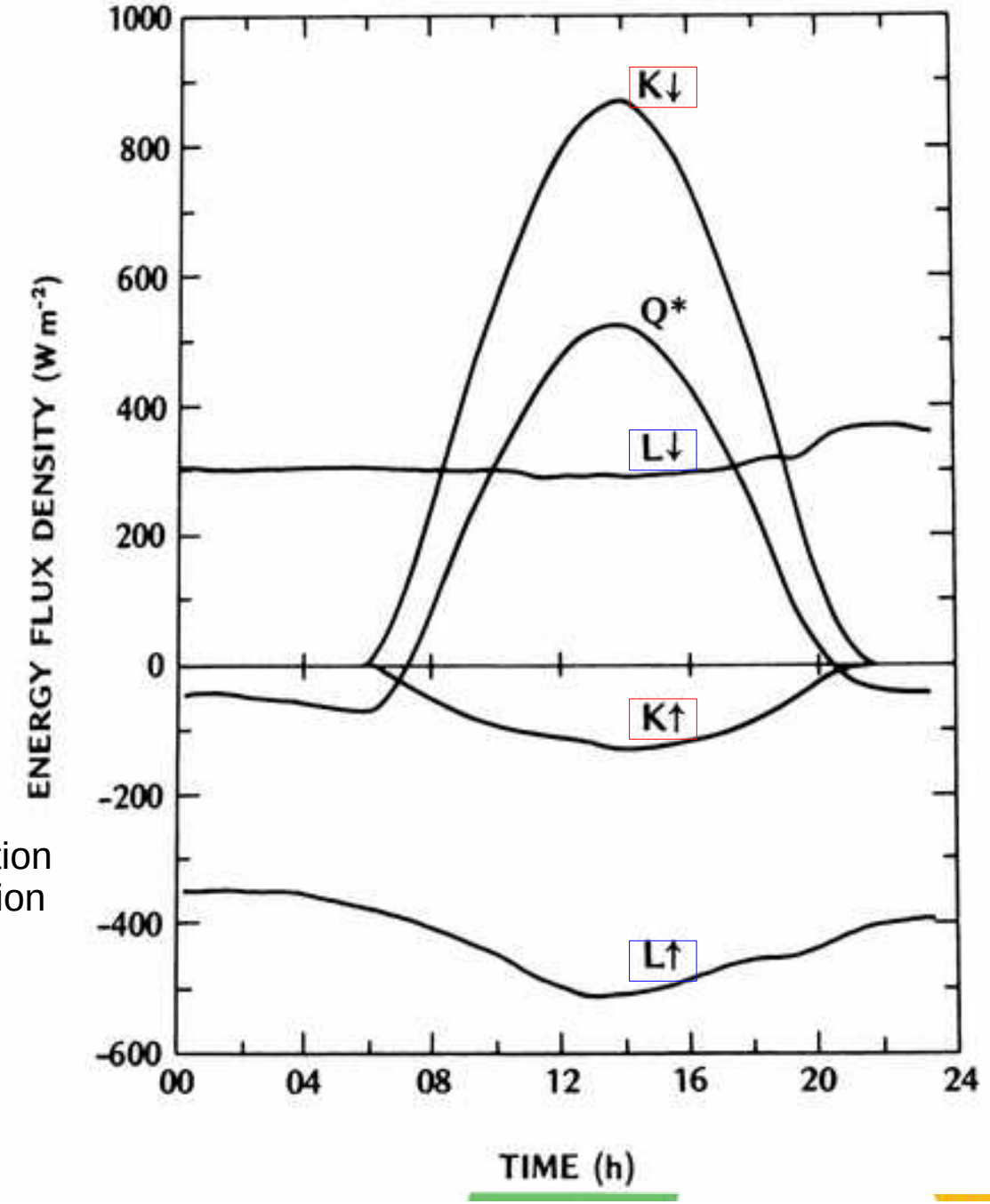
Radiation budget components for 30 July 1971, at Matador, Saskatchewan (50 °N) over 0.2 m stand of native grass. Cloudless skies in the morning, increasing cloud in the later afternoon and evening (after Riply an Redmann, 1976).



K↓ = short-wave incoming solar radiation
K↑ = short-wave reflected solar radiation
L↓ = long-wave incoming radiation
L↑ = 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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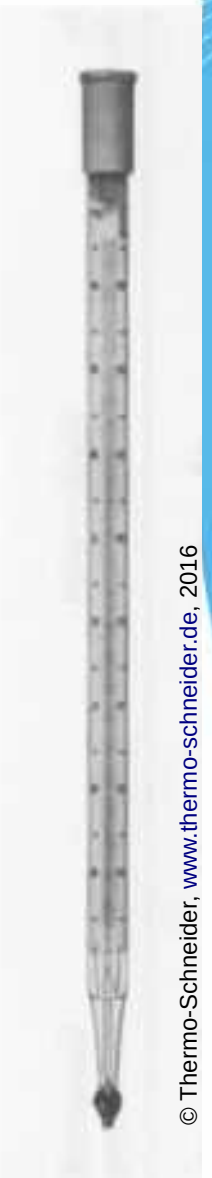

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Climatological parameter based on air temperature observations

Averages: daily, monthly, seasonally, yearly, …

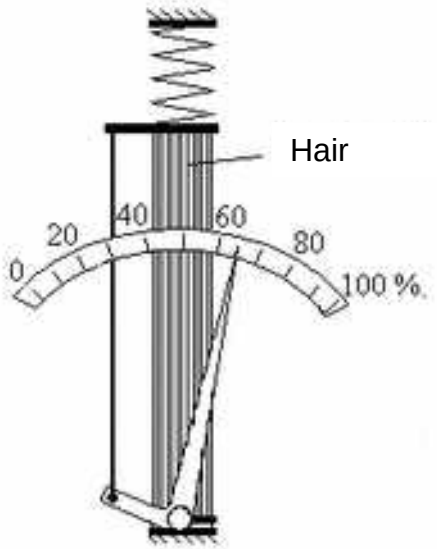
Extremes: maxima, minina (daily, monthly, yearly, …)

Number of days with
- Tmin <-10 °C, cold day
- Tmin < 0 °C, frost day
- Tmin > 20 °C, tropical night
- Tavg < 0 °C, winterday
- Tmax < 0 °C, ice day
- Tmax > 25 °C, summerday
- Tmax > 30 °C, hot day
- Tavg > 5 °C, growing season day
- Tavg < 12/15 °C, heating day

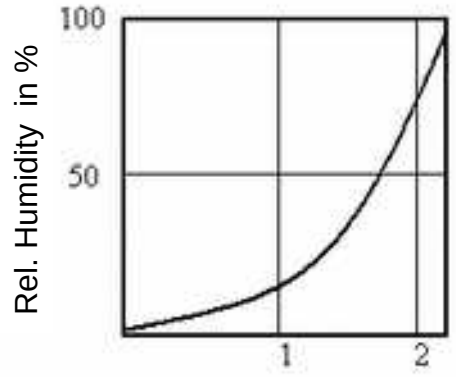
Return periods

Humidity

Hair hygrometer



Expansion of the hair



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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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Climatological parameter based on wind observation

Averages: daily, monthly, seasonally, yearly, …
Extremes: maxima, minina (daily, monthly, yearly, …)
Number of days with wind speed ≥ 8 Beaufort, >21 m/s

Precipitation – rain and snow

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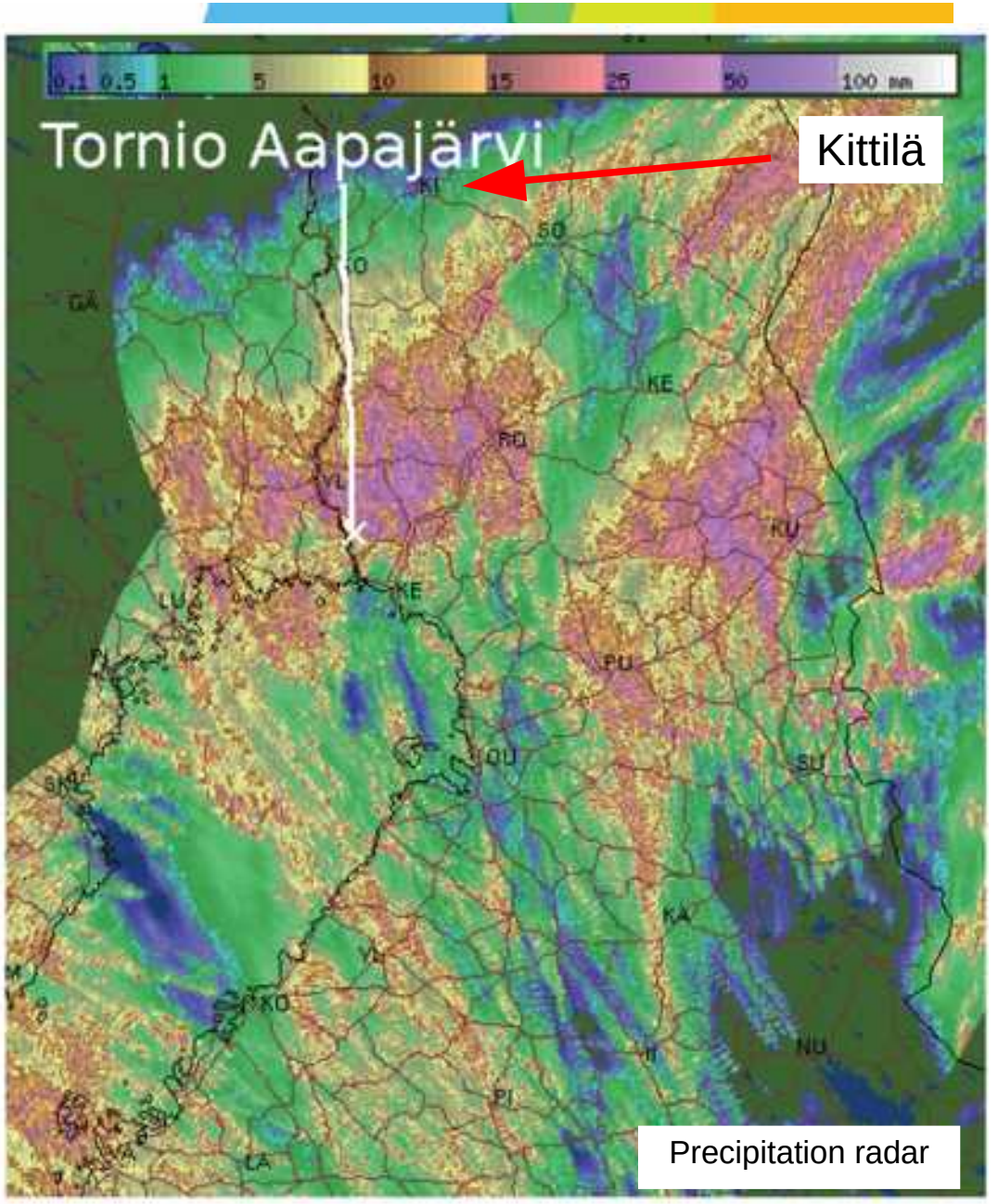
© wikipedia, 2014

weighing-type precipitation gauge



© Finnish Meteorological Institute, 2011

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

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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 ≥ 1.0 mm
R ≥ 10.0 mm
R ≥ 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

Ultra-sonic sensor

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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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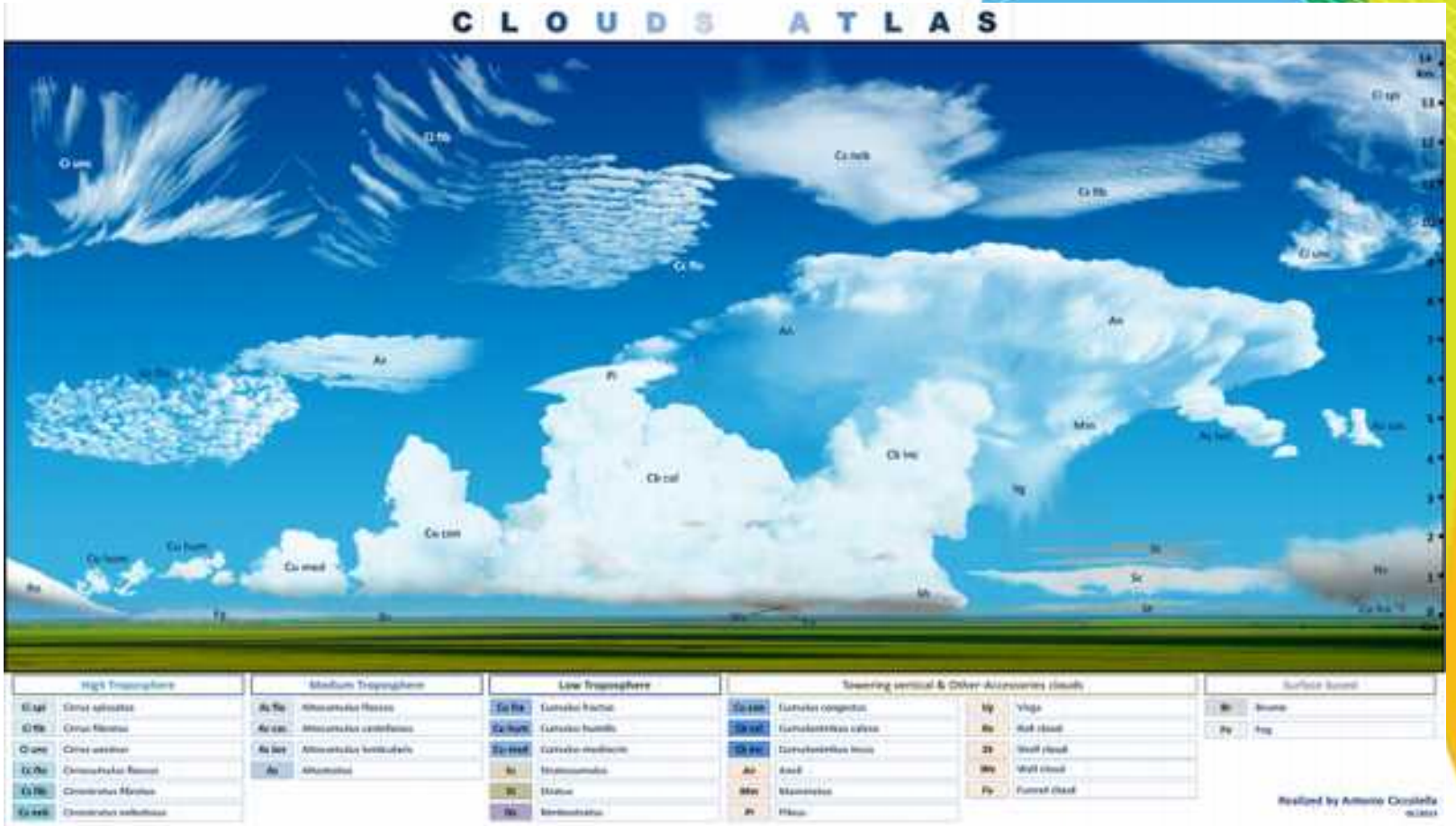
Cloudiness and visibility



Ceilometer

Present weather sensor

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Cloud cover		Symbol
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	

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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

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Solar short-wave radiation

Terrestrial long-wave radition

…..

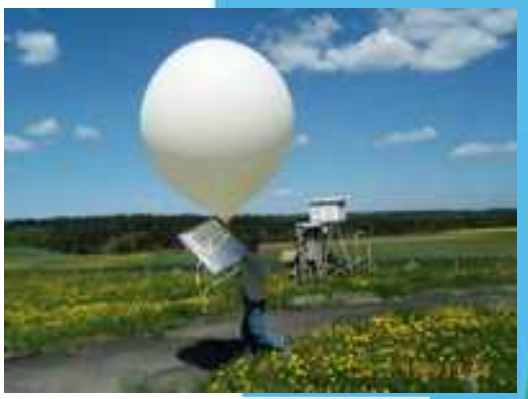
Radiosonde, T, RH, p, wind

Satellites

…..

Air pressure, p

Evapotranspiration



© http://www.zfx.de/sonde/

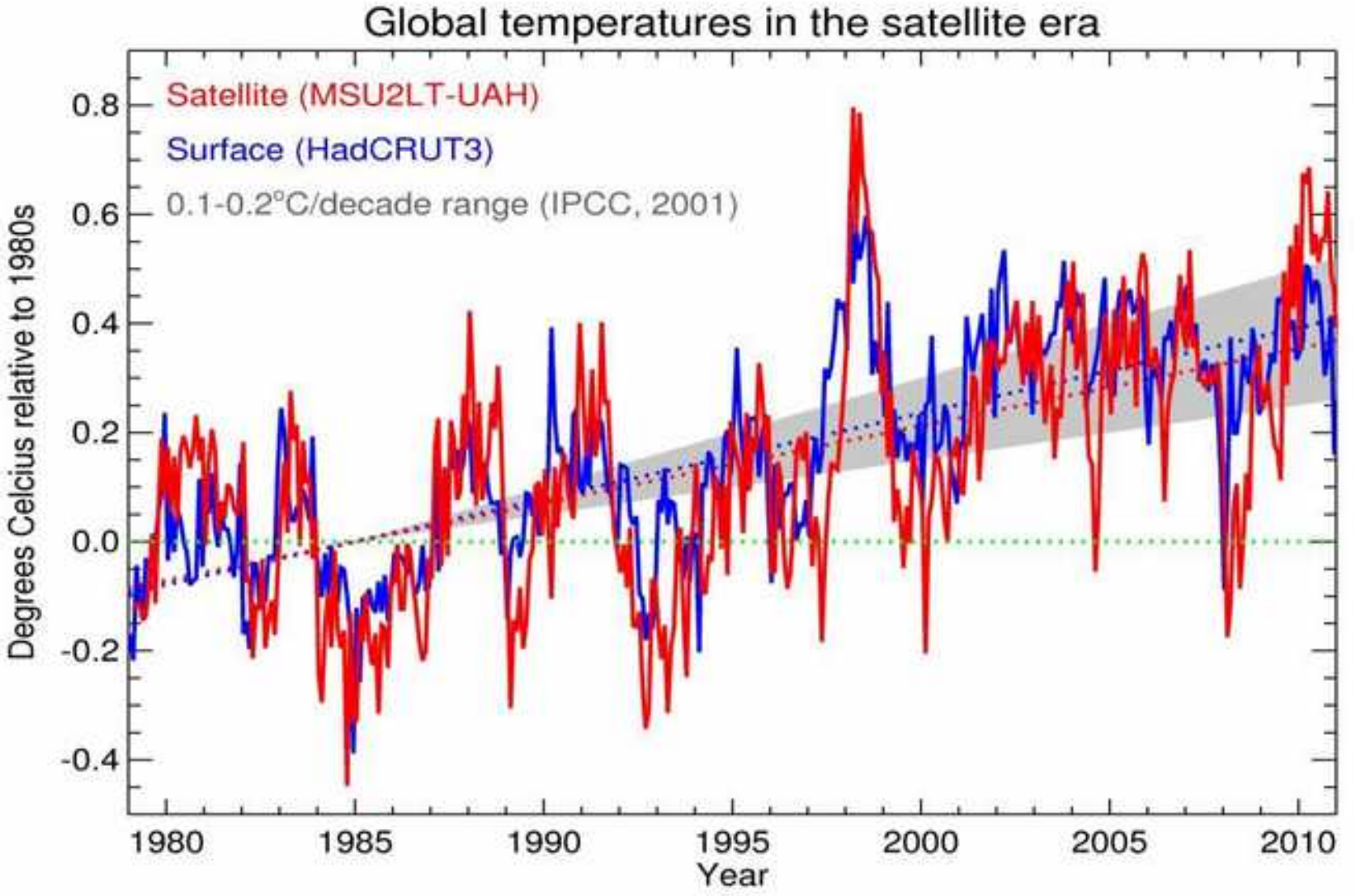
Radiosonde launch

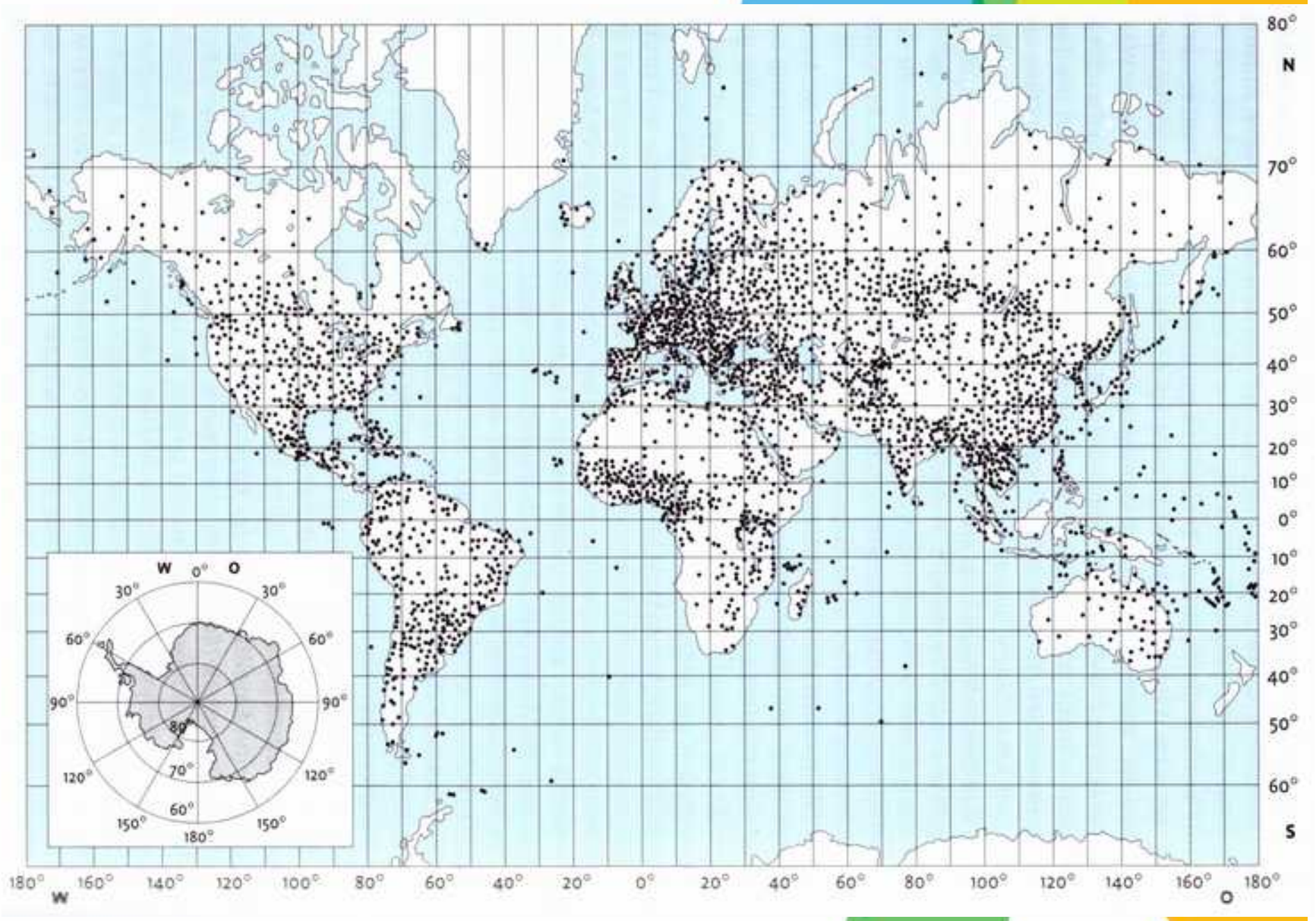
© https://commons.wikimedia.org/w/index.php?curid=7559335

Net radiometer

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

GEOS – 8, US – weather satellite


Global temperatures in the satellite era
Satellite (MSU2LT-UAH)
Surface (HadCRUT3)
0.1-0.2°C/decade range (IPCC, 2001)
Degrees Celcius relative to 1980s
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
1980
1985
1990
1995
2000
2005
2010
Year



Global networkof ground weather station, after WMO 1981

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

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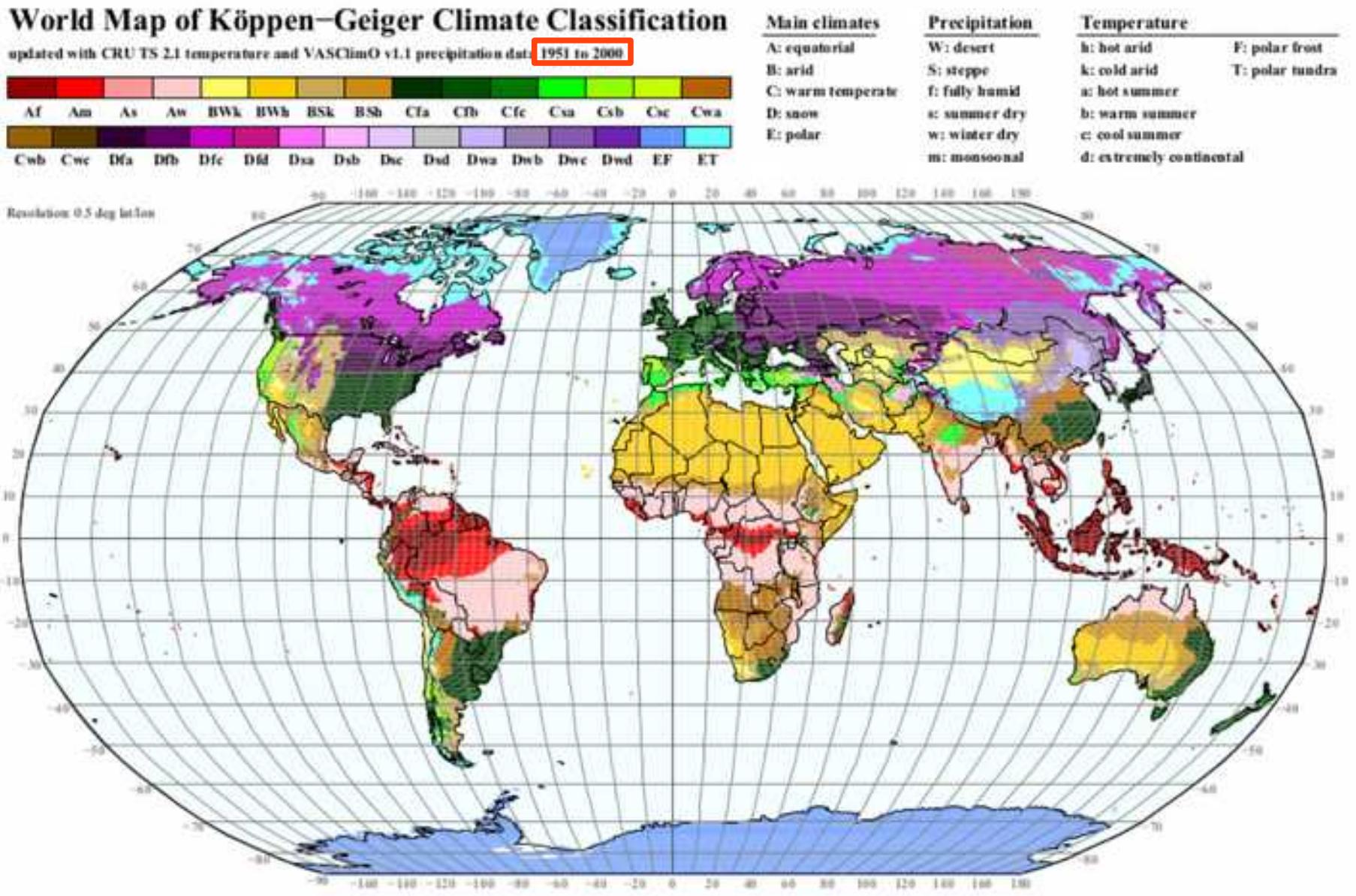
Climate classification

Empiric climate systems



© Meteorol. Z.,15, 2006 M. Kottek et al.: World Map of the Köppen-Geiger climate classification updated

Climate classification

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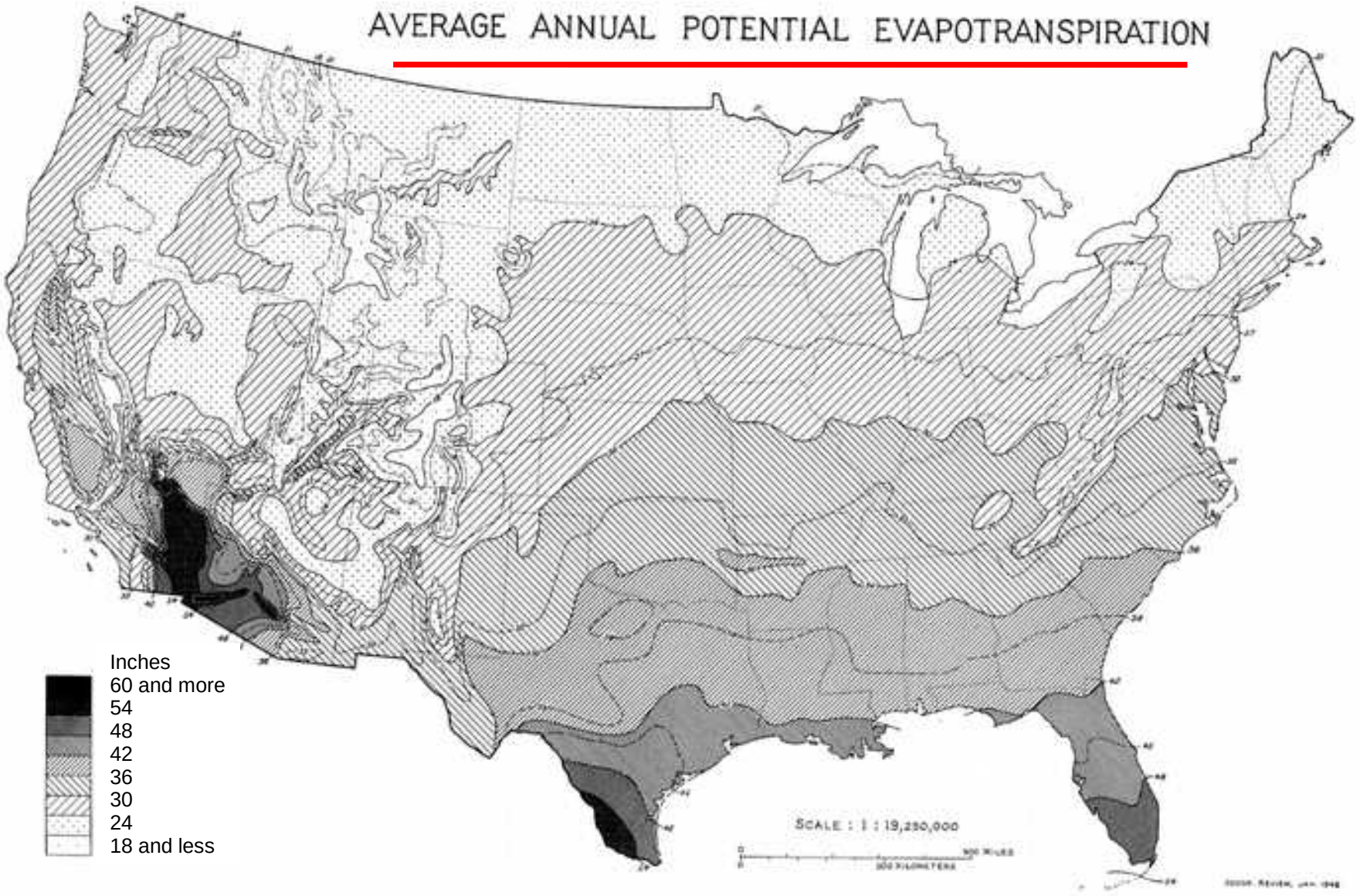
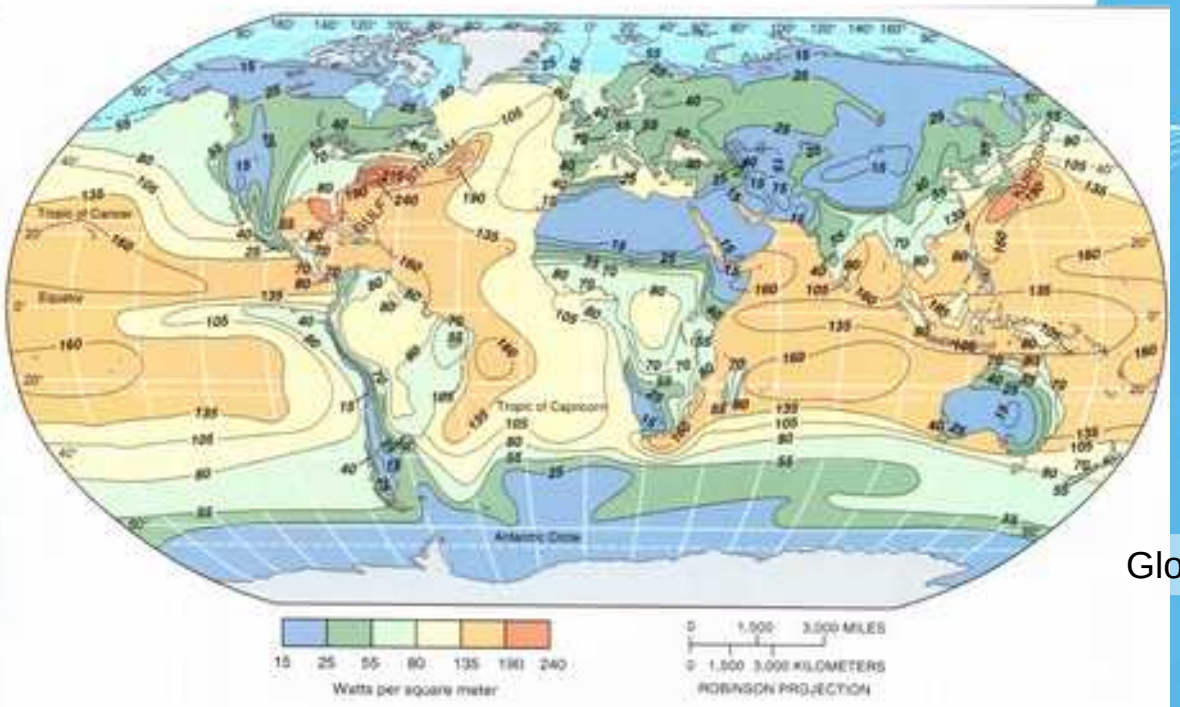
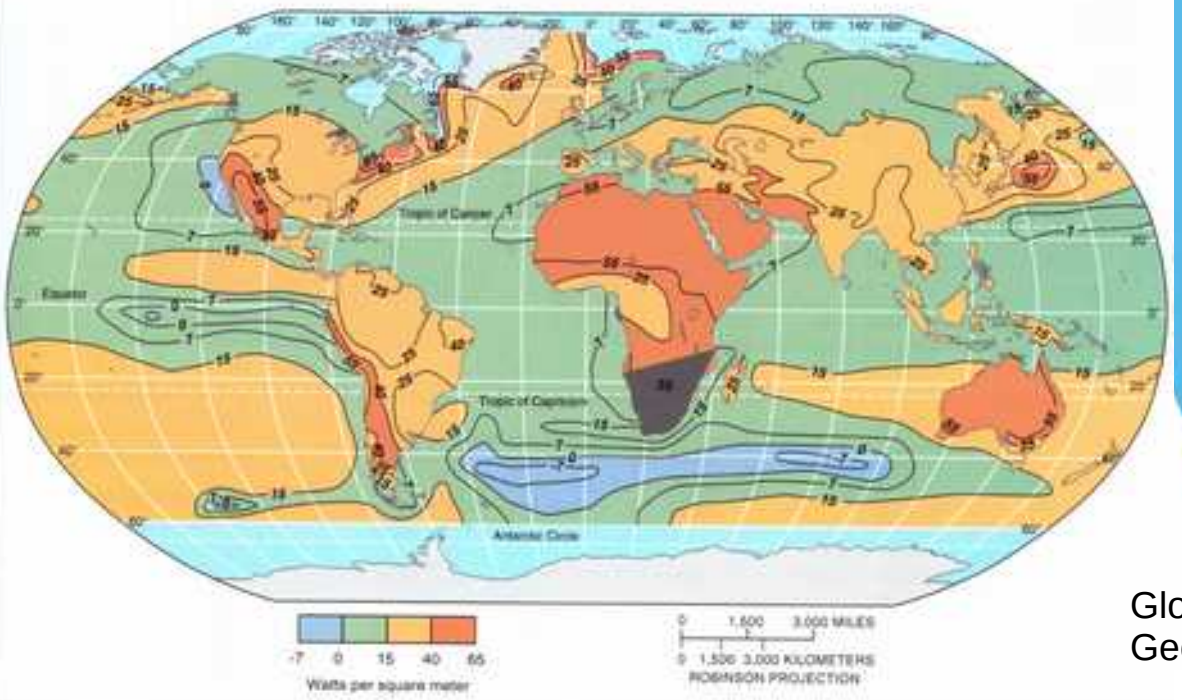


An Approach toward a Rational Classification of Climate
C. W. Thornthwaite, Geographical Review, Vol. 38, No. 1. (Jan., 1948), pp. 55-94.

Genetic climate systems



Global heat of evaporation



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

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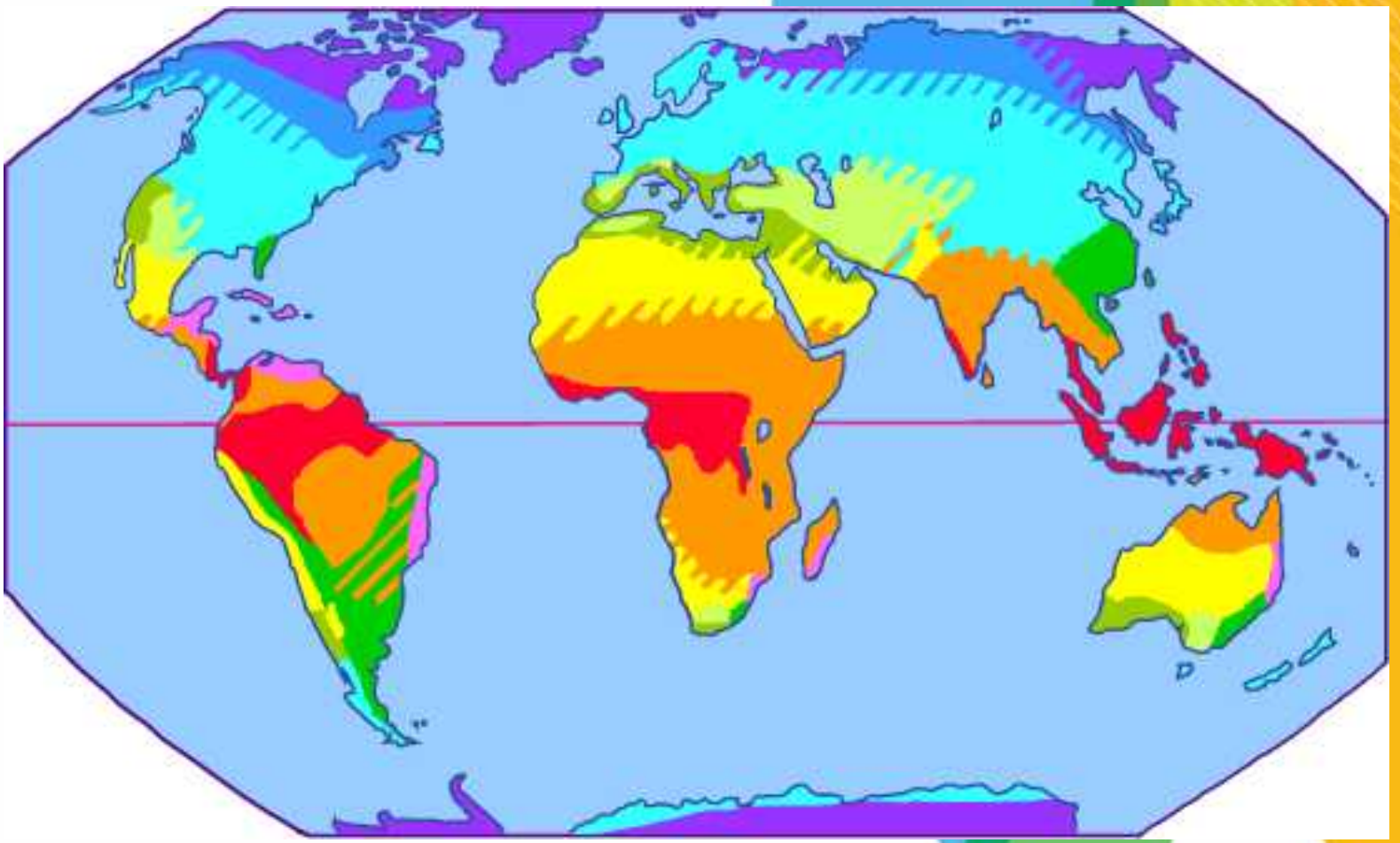
Genetic climate systems



Flohn, 1950

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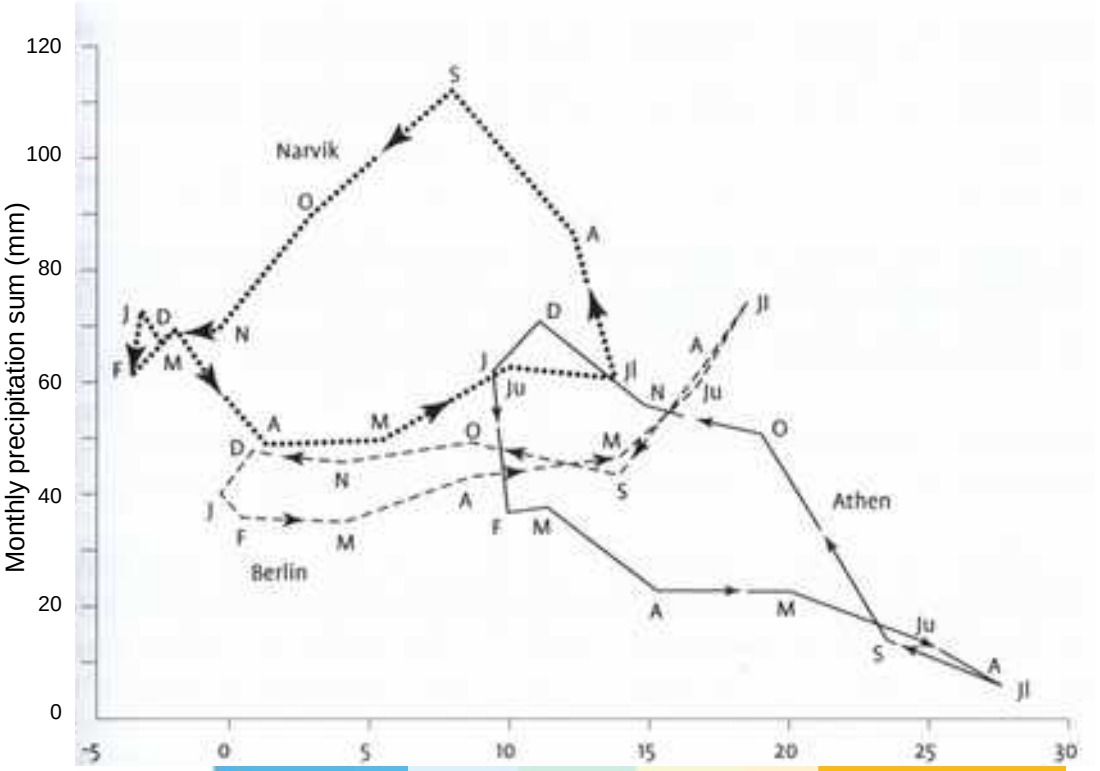
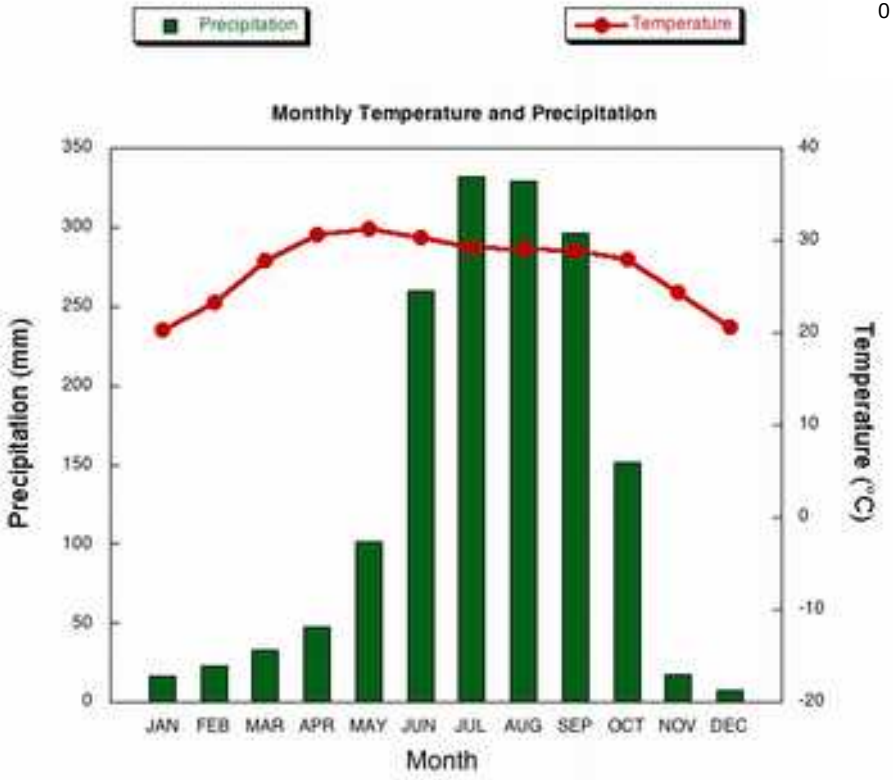
Climatological synopsis

Climatological diagrams





Index of continentality
maritime/continental climate
…..

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

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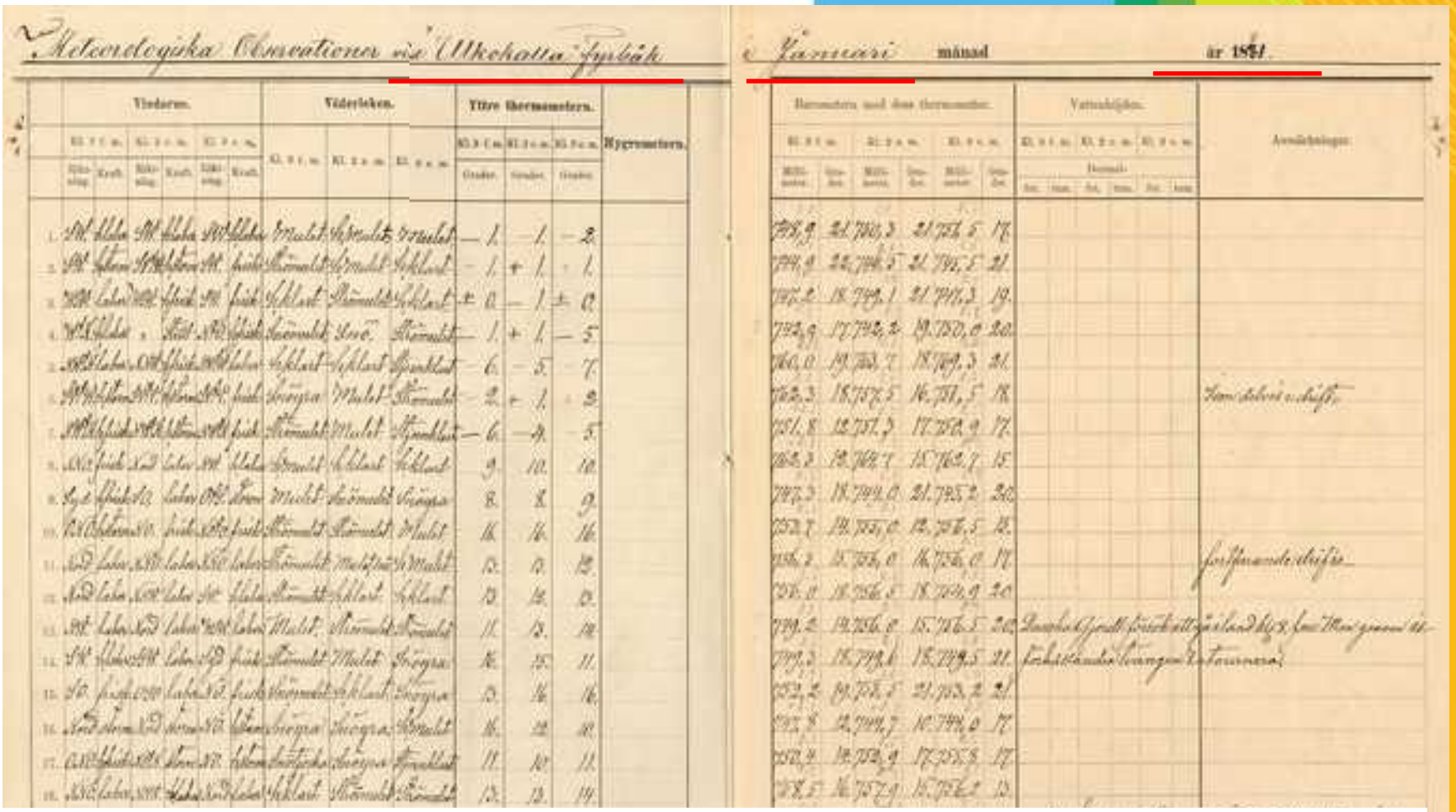
Climate data – historic, synoptic, re-analysed, satellite, radar

Wind - air temperature - air pressure



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

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

```
IIiii or IIIII YYGGi 99LLL QLLLL
iihVV 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!

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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 Rrecipitation Recon. (Land)
HADSLP 2
HADISST
NOAAERSST
NOAAERSST V4
COBE
NASA NVAP
ERA 20C

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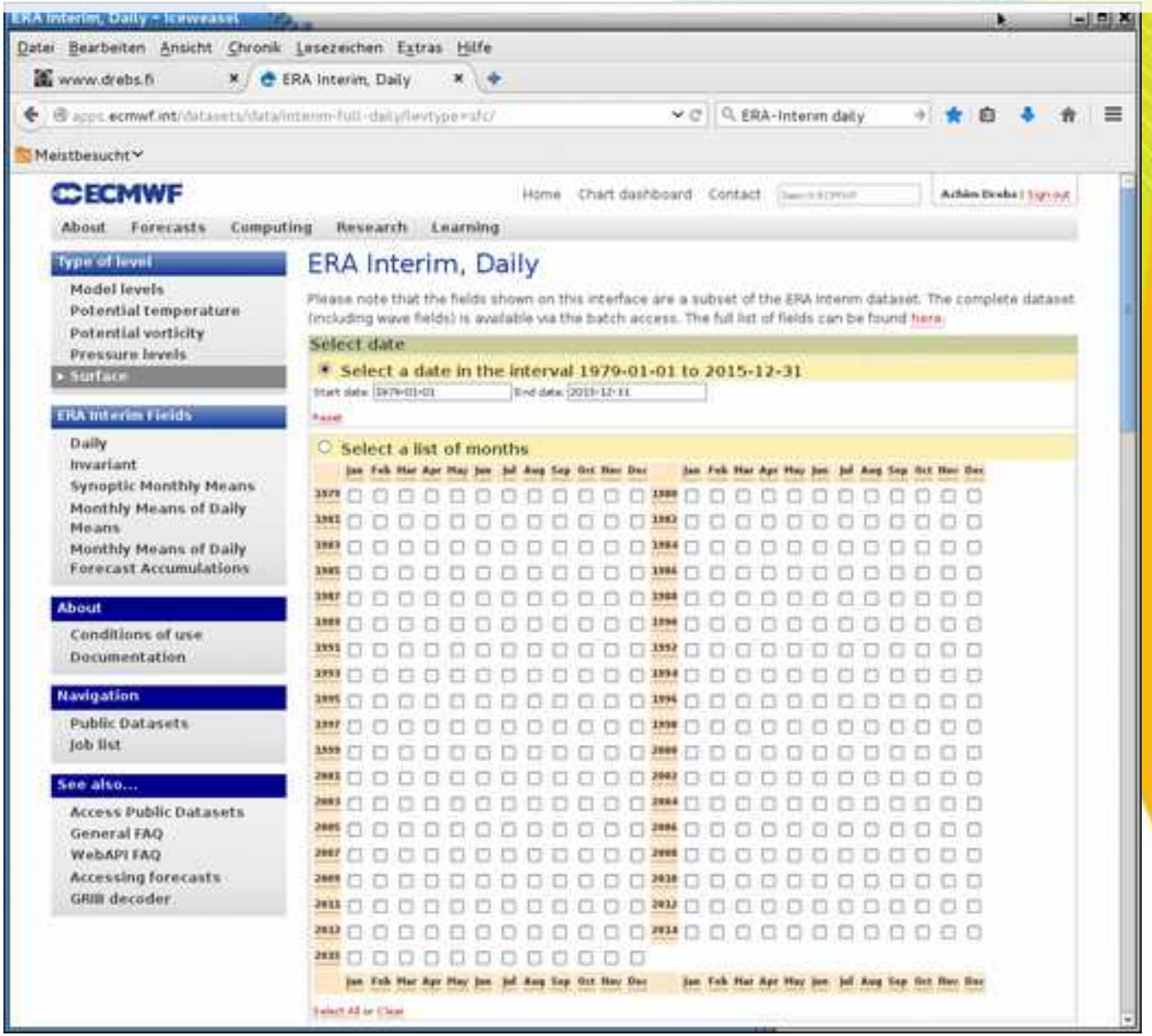
Climate data – historic, synoptic, re-analysed, satellite, radar



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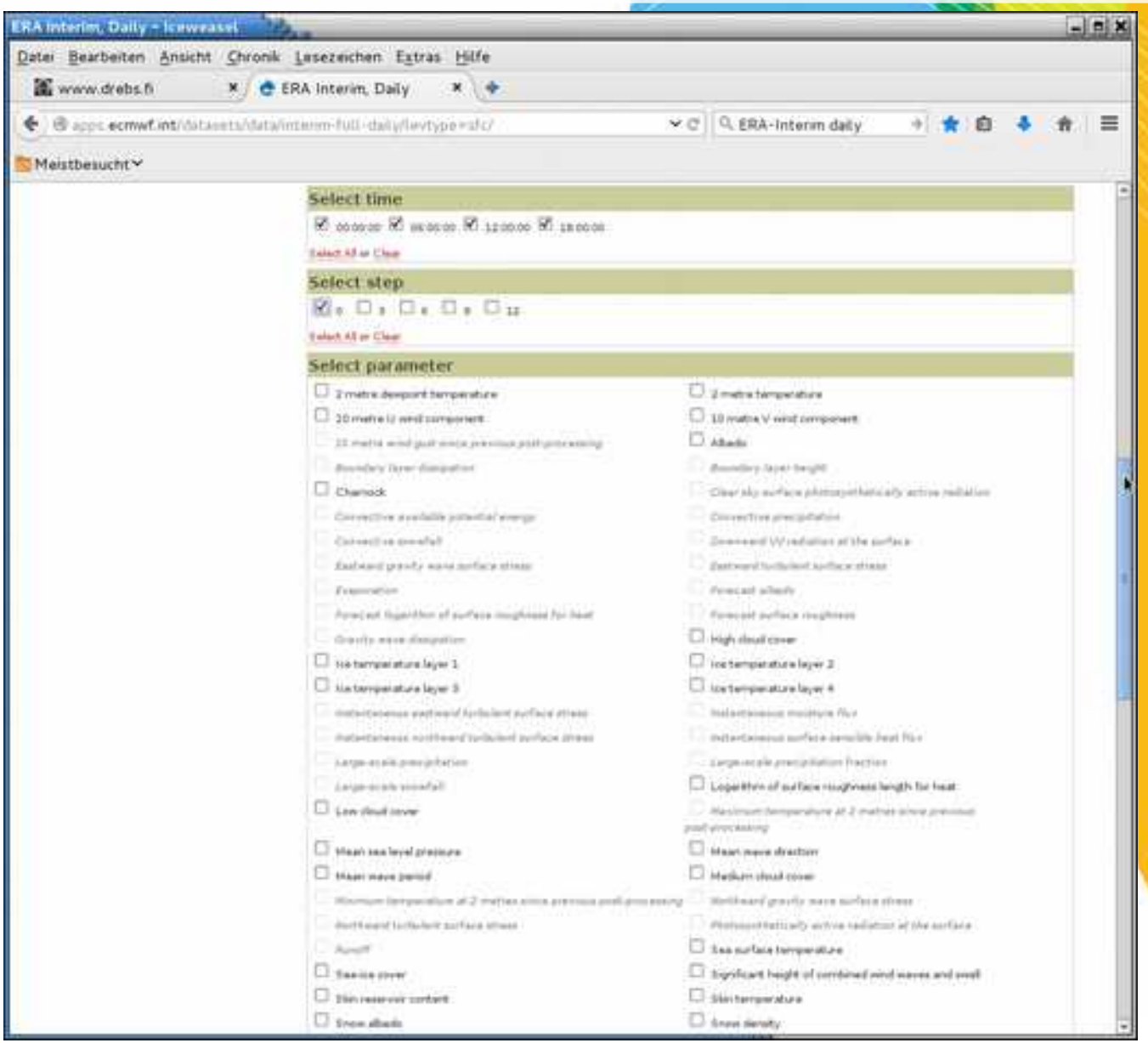

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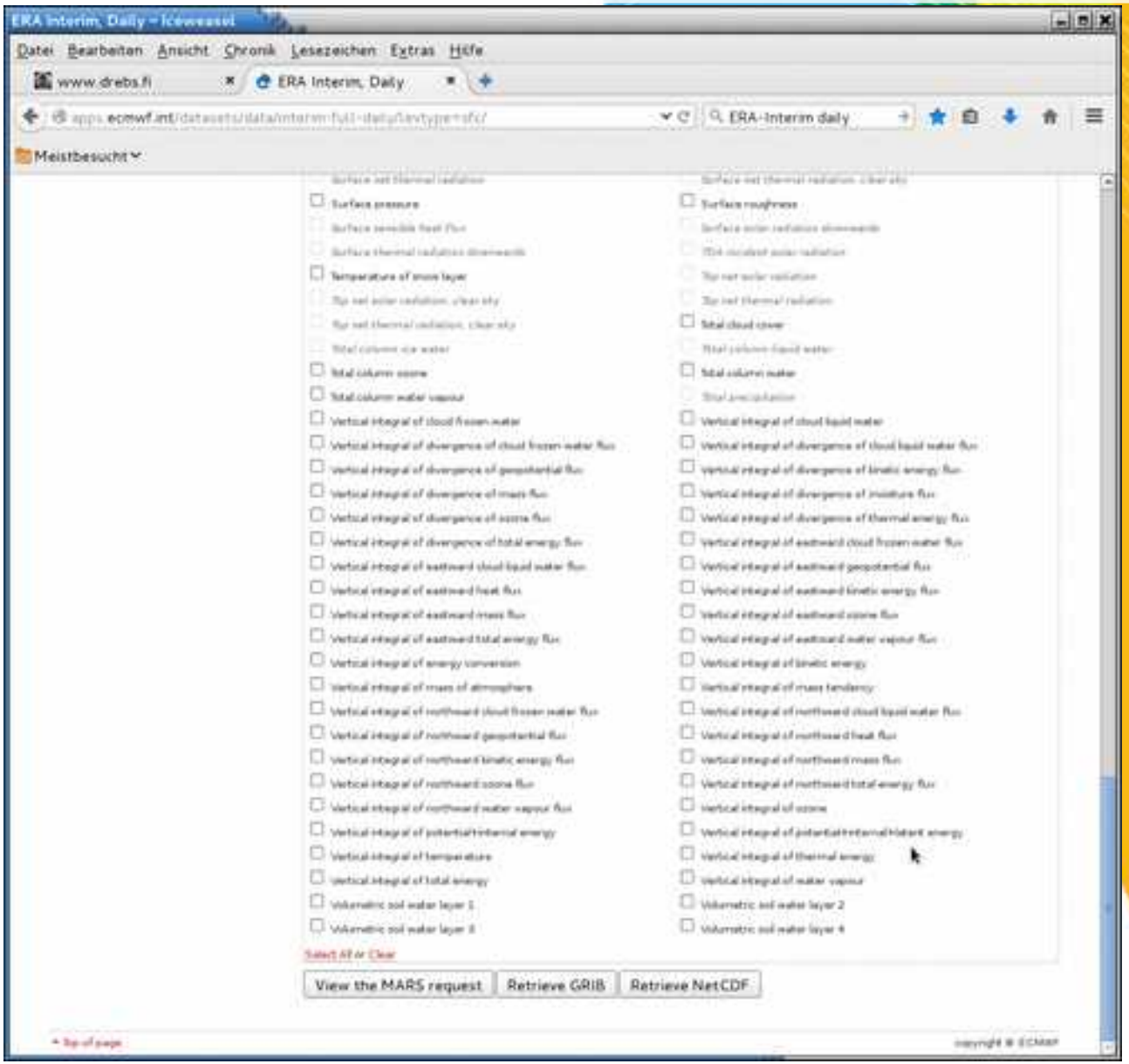

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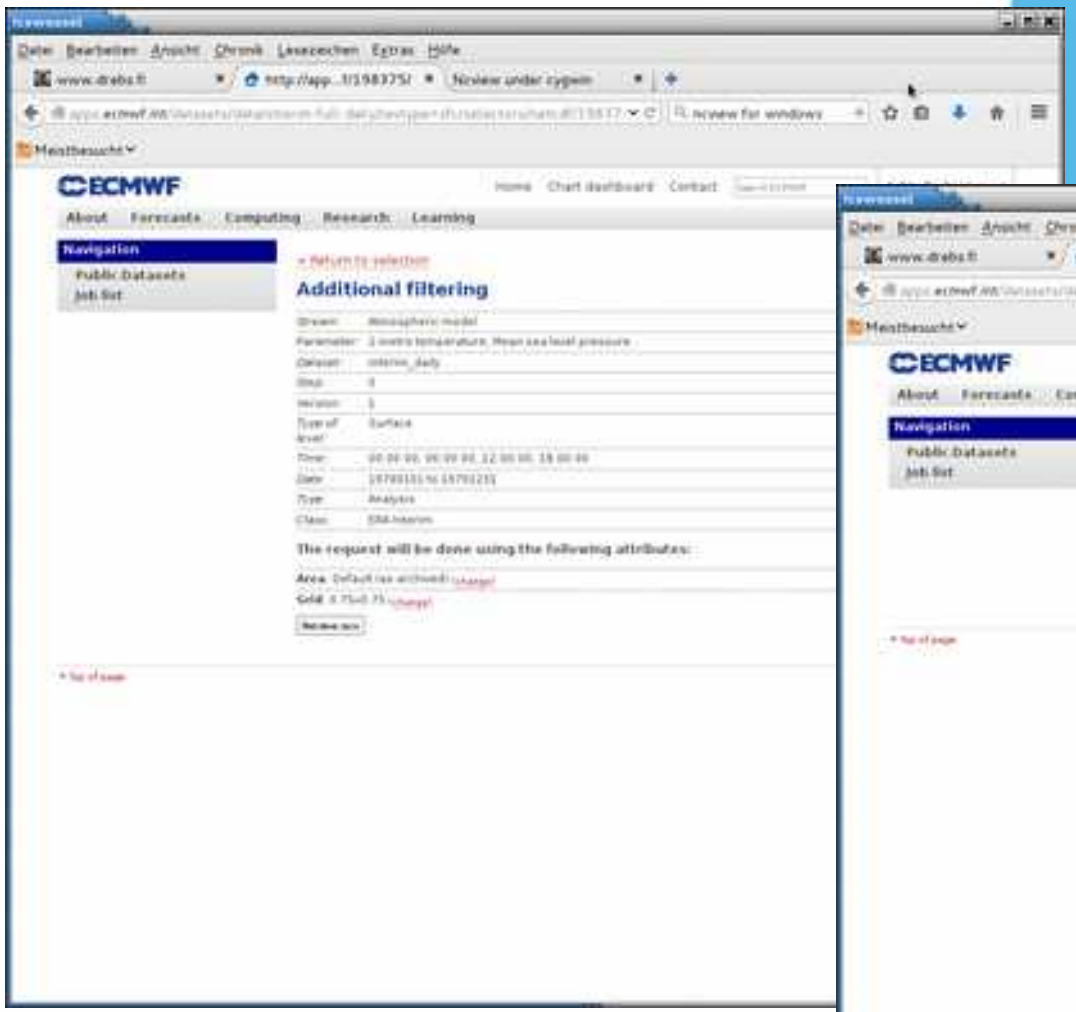

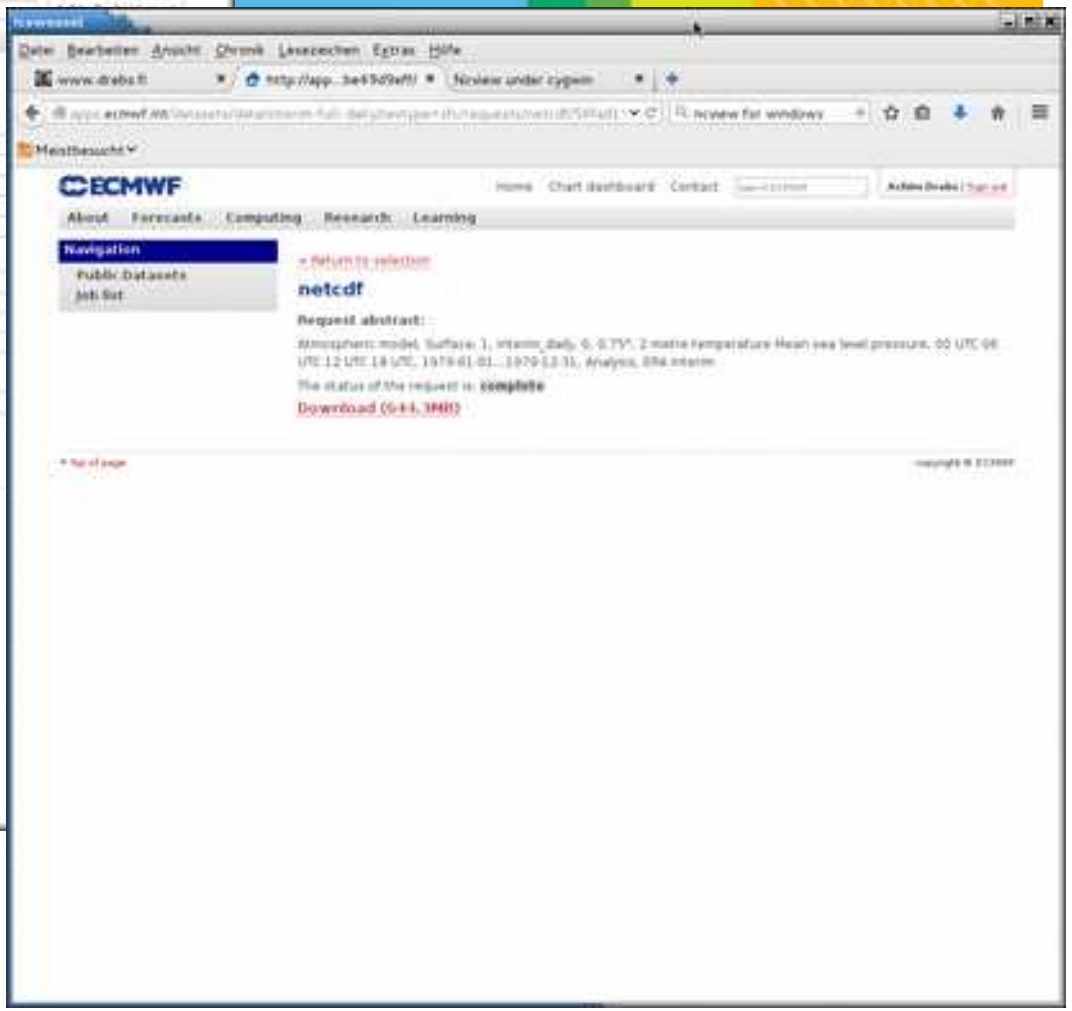

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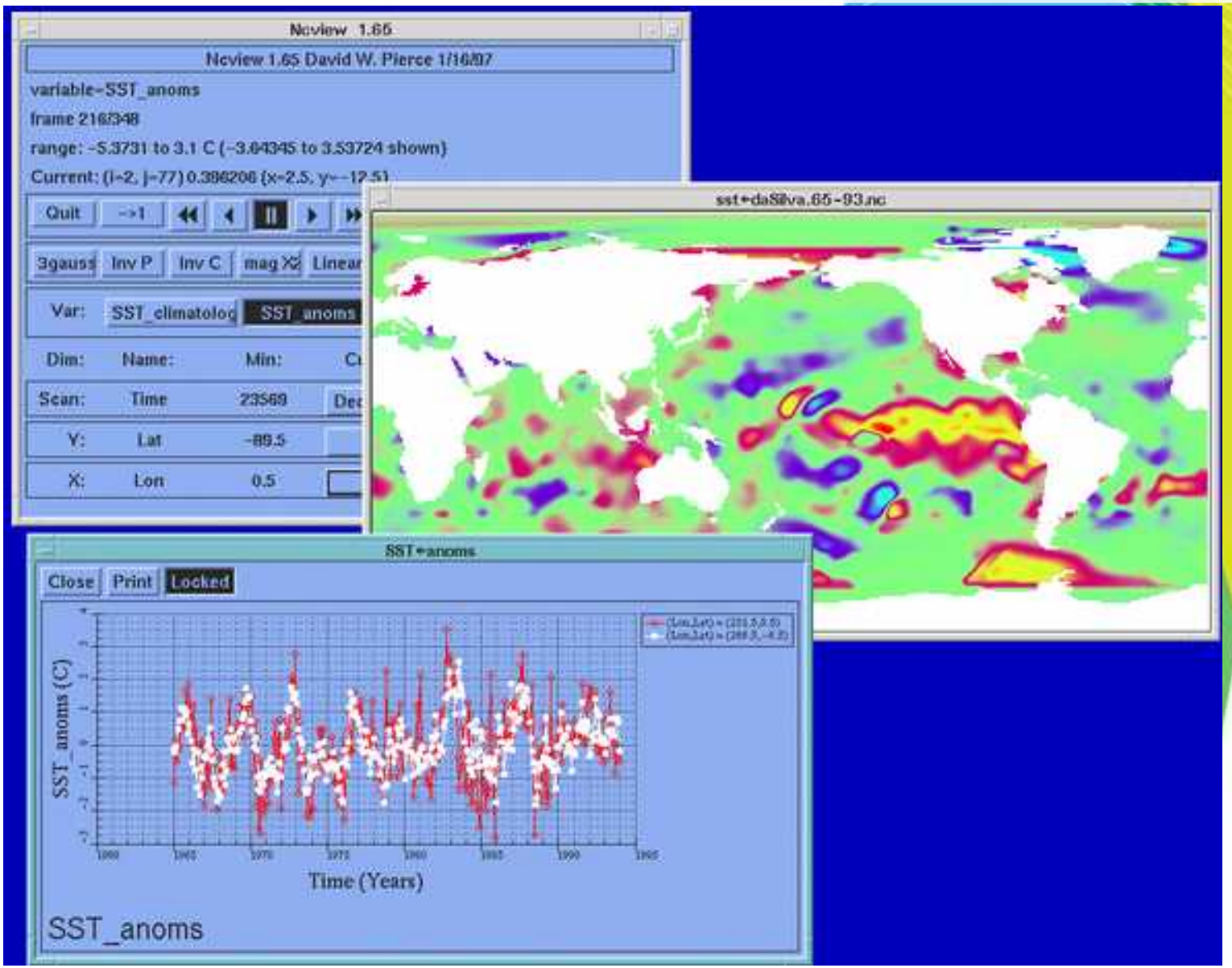

Using the

Ncview - software

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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

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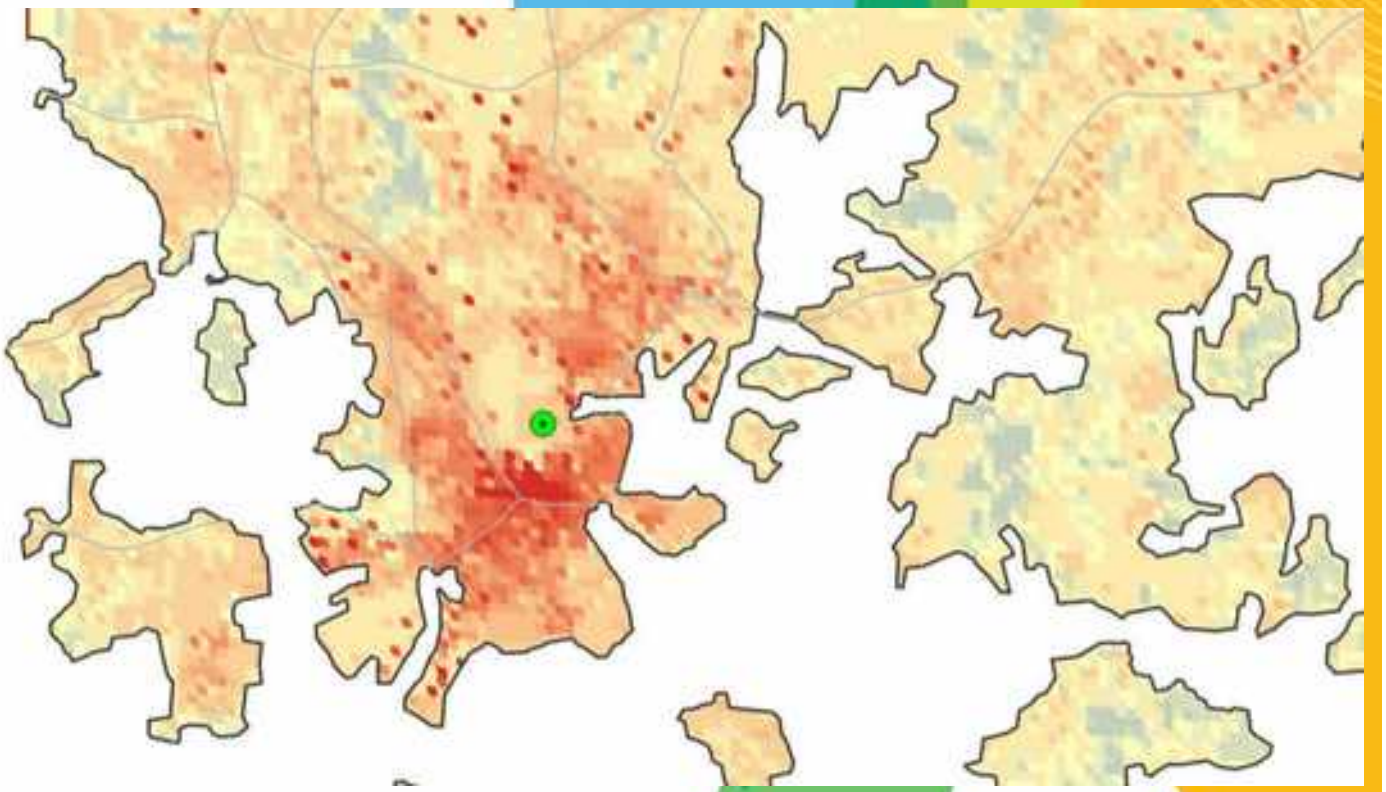
Climatological applications – Urban Climate

The urban heat island of city centre Helsinki



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Climatological applications – Urban / Human Climate

Green wall

Green roof

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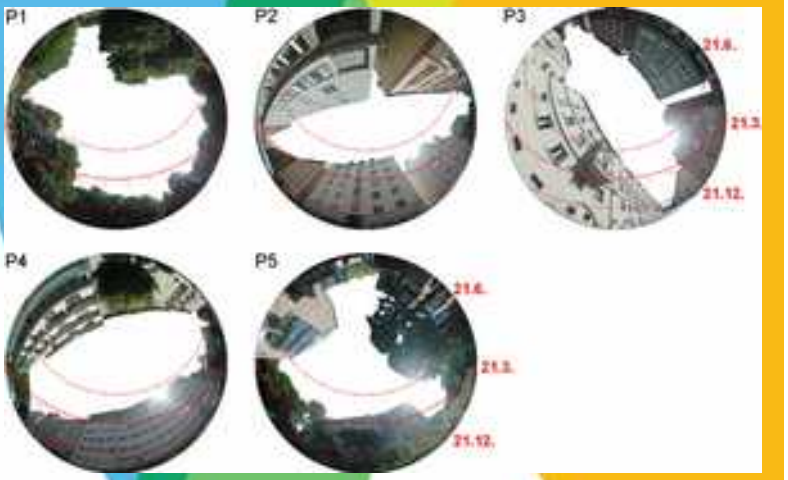
Human comfort



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

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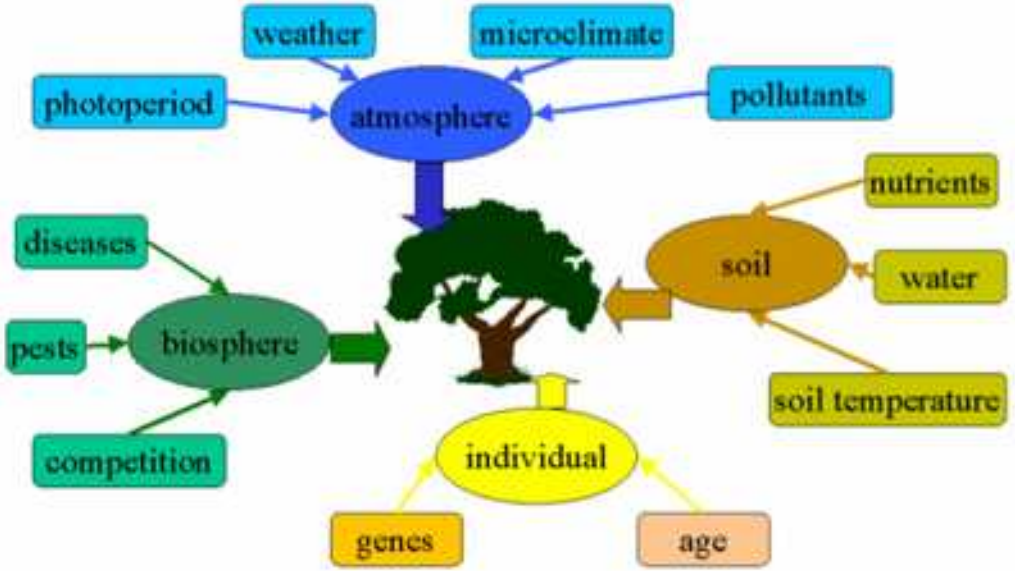
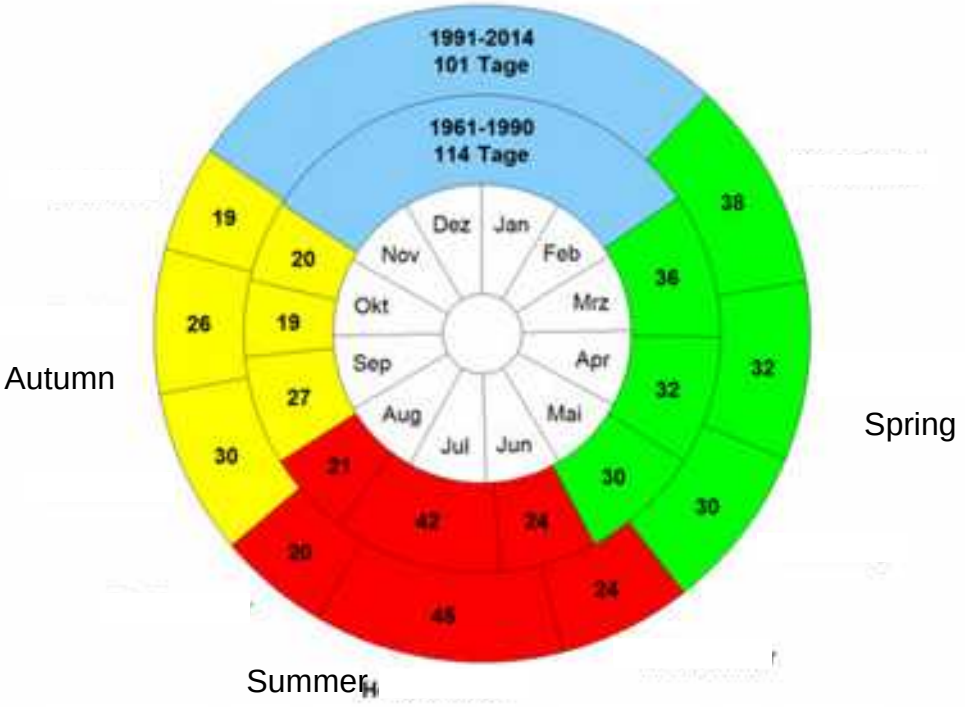
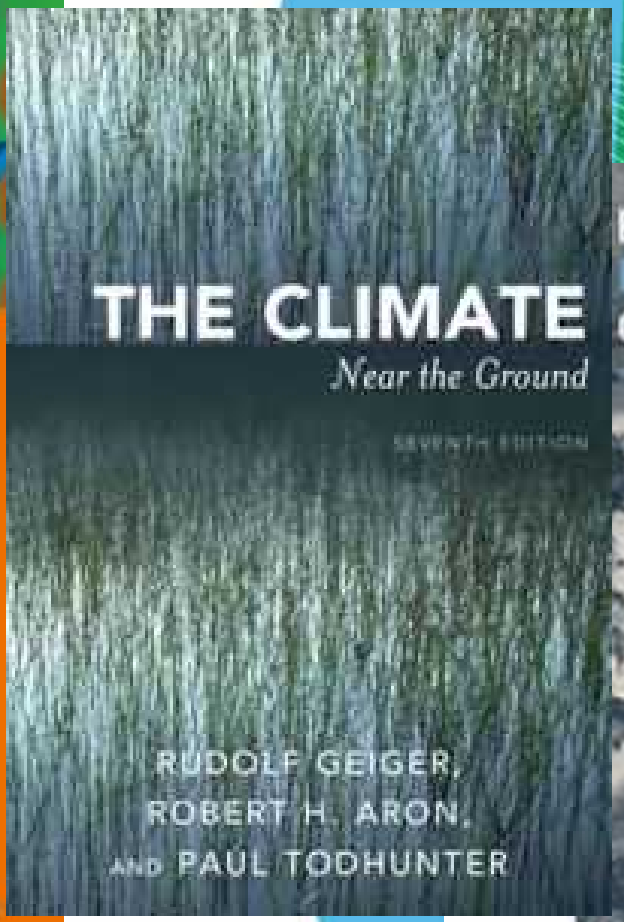
Climatological applications – Phenology



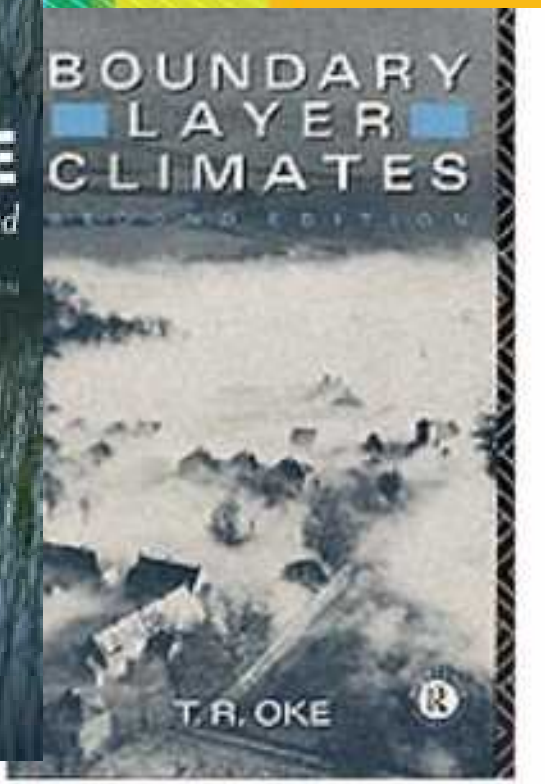
Phenological clock for Rhineland-Palatinate



2013
660 pages



2009
642 pages



1987
464 pages

Literature ….

… and all kind of books about general climatology