Climate Change

Facts about a Global Issue

Climate Change: Weather or Climate? Man or Nature?

What is Climate? Difference Climate – Weather ? Seasons ?

Which are the global climate regions ?

What contributes to Climate ?

How can I get Climate Information ?

How was the Climate 100, 1000, 10000, 100000 years ago ?

How to forecast Climate ?

Which are the main aspects of the Climate Change discussion ?

What about CO2? Good for tomatoes ? Or harmful to Global Climate ?

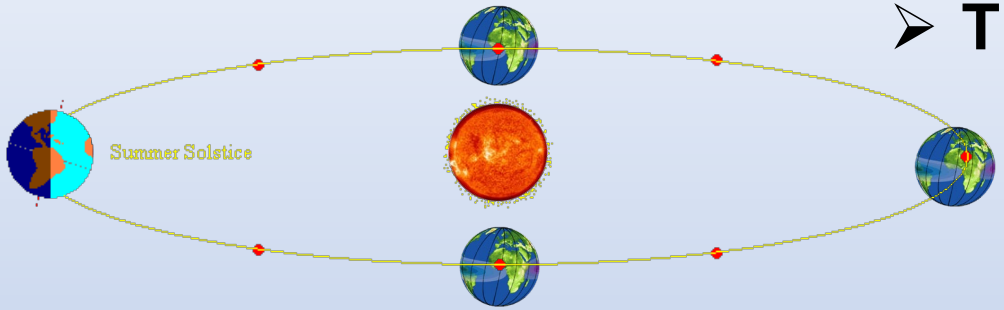
What is Climate ?

Climate is, what you expect – Weather is, what you get.

- Statistical Analysis of time-series (Annual Variation) of weather
- Statistical correlation and causality (Storks/birthrate)
- Statistical Charactristics (Mean- / Extremevalues,)
- /Meteorological / geographical properties result in Climate Zones (maritim / kontinental / tropical, arid, humid …)

WHY DO WE HAVE THE GLOBAL CIRCULATION ?

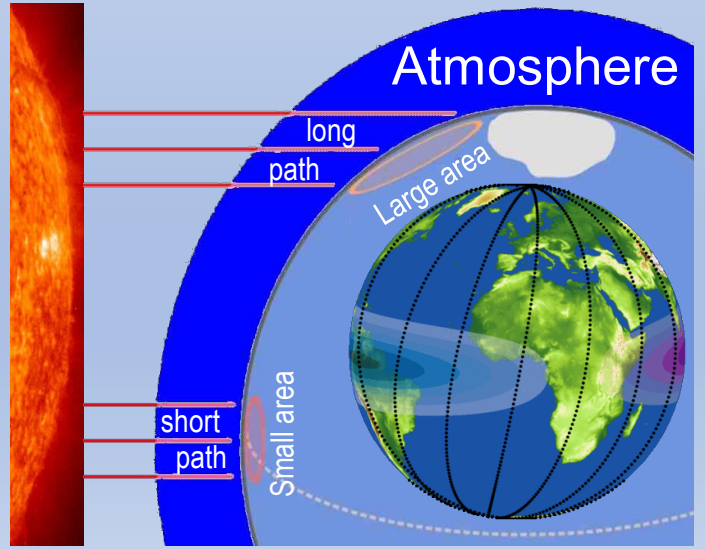
- **The Sun is shining …**

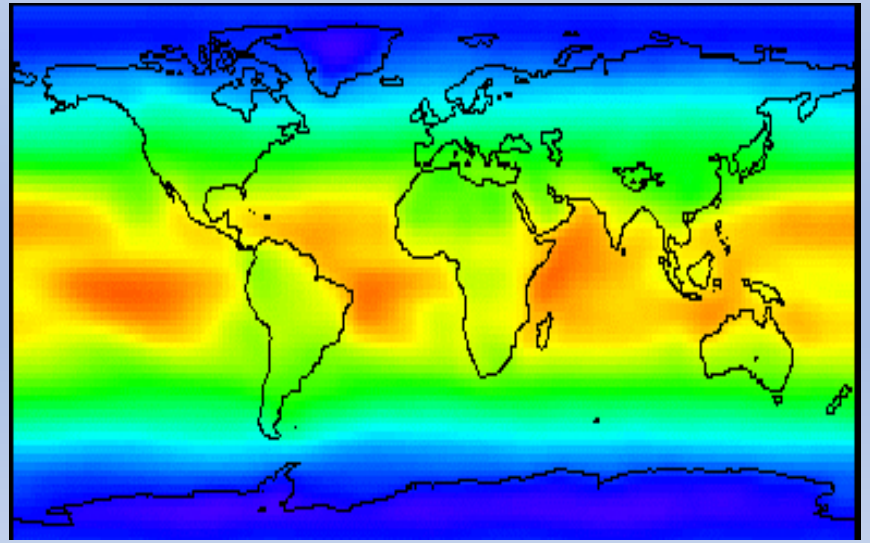


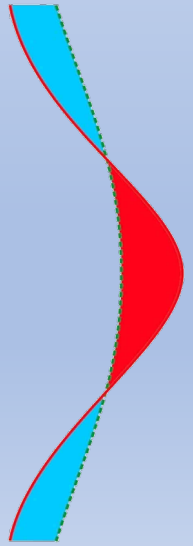
- **The Earth…**
  - …. is a sphere, circumference 40000 km / 21600 nm
  - … orbits the Sun 1 / year
  - … rotates around its axis 1 / day

- **This results in …**

… Meridional (N/S) Temperature-Gradient, which directly (physically) drives the Global Circulation.

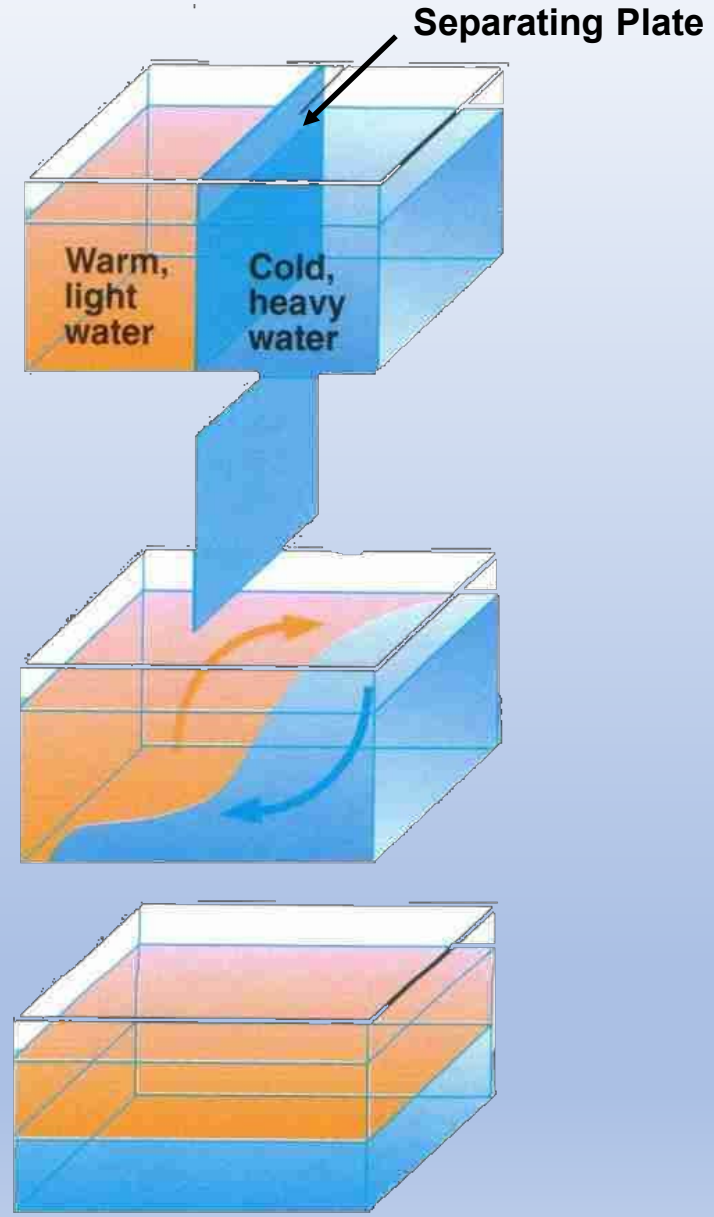




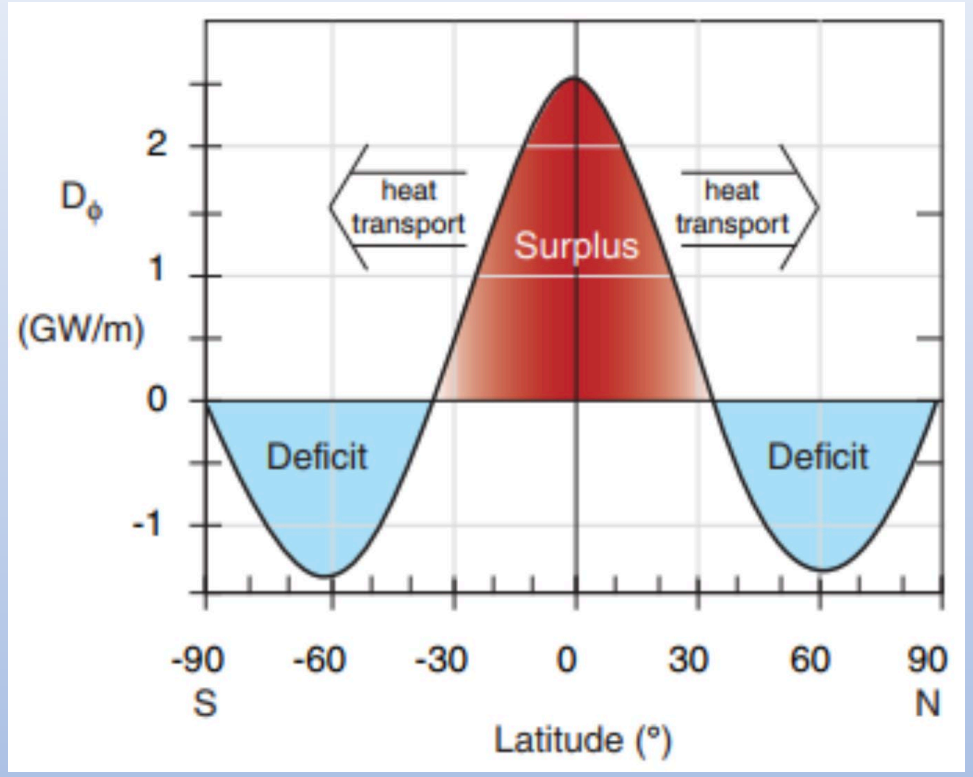


Energy Aspects

$E_{pot} + E_{kin} = const.$



$E_{pot} > min$



South Pole Equator North Pole

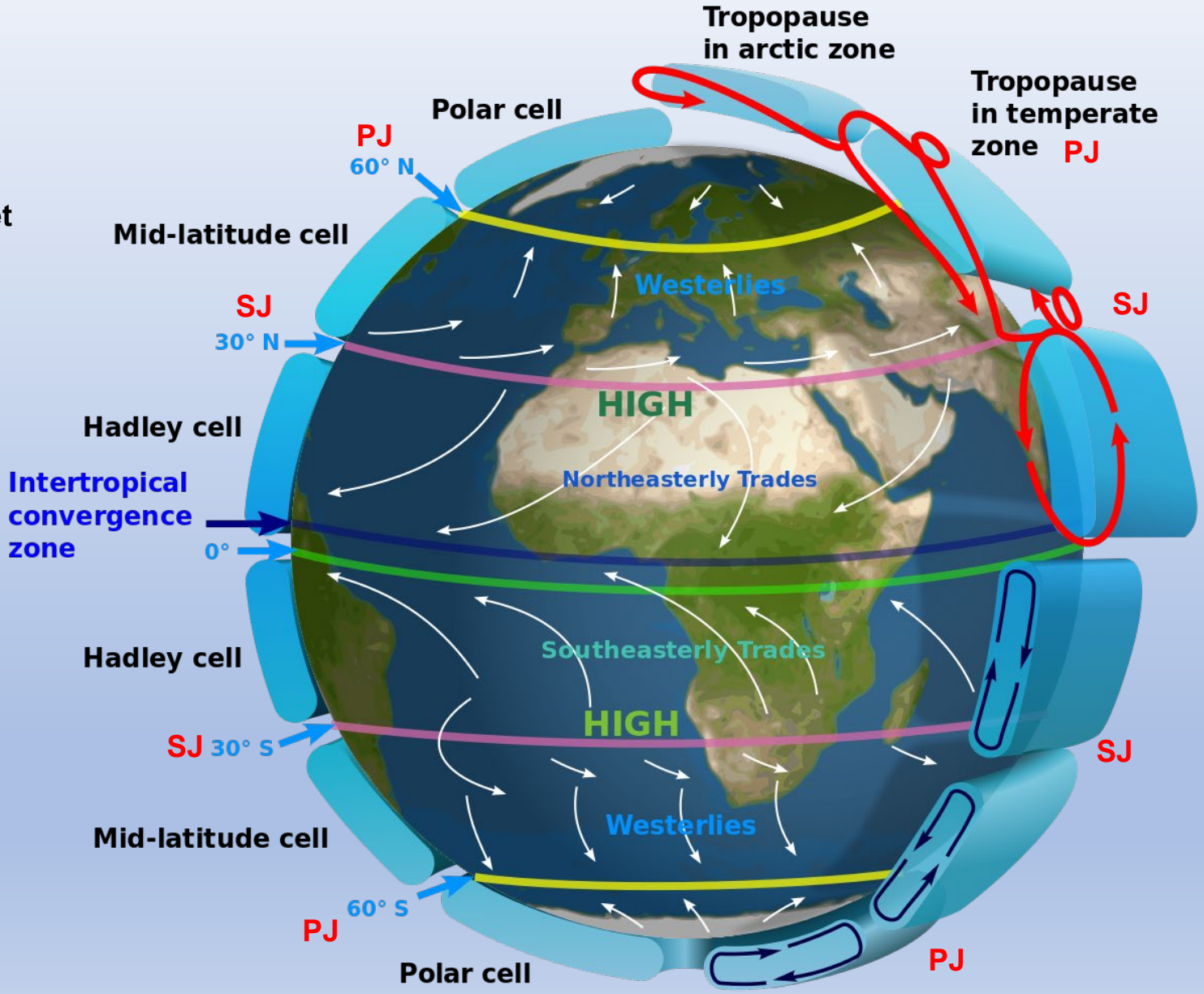
$E_{pot} = min$

E_{pot} Decrease <=> E_{kin} Increase

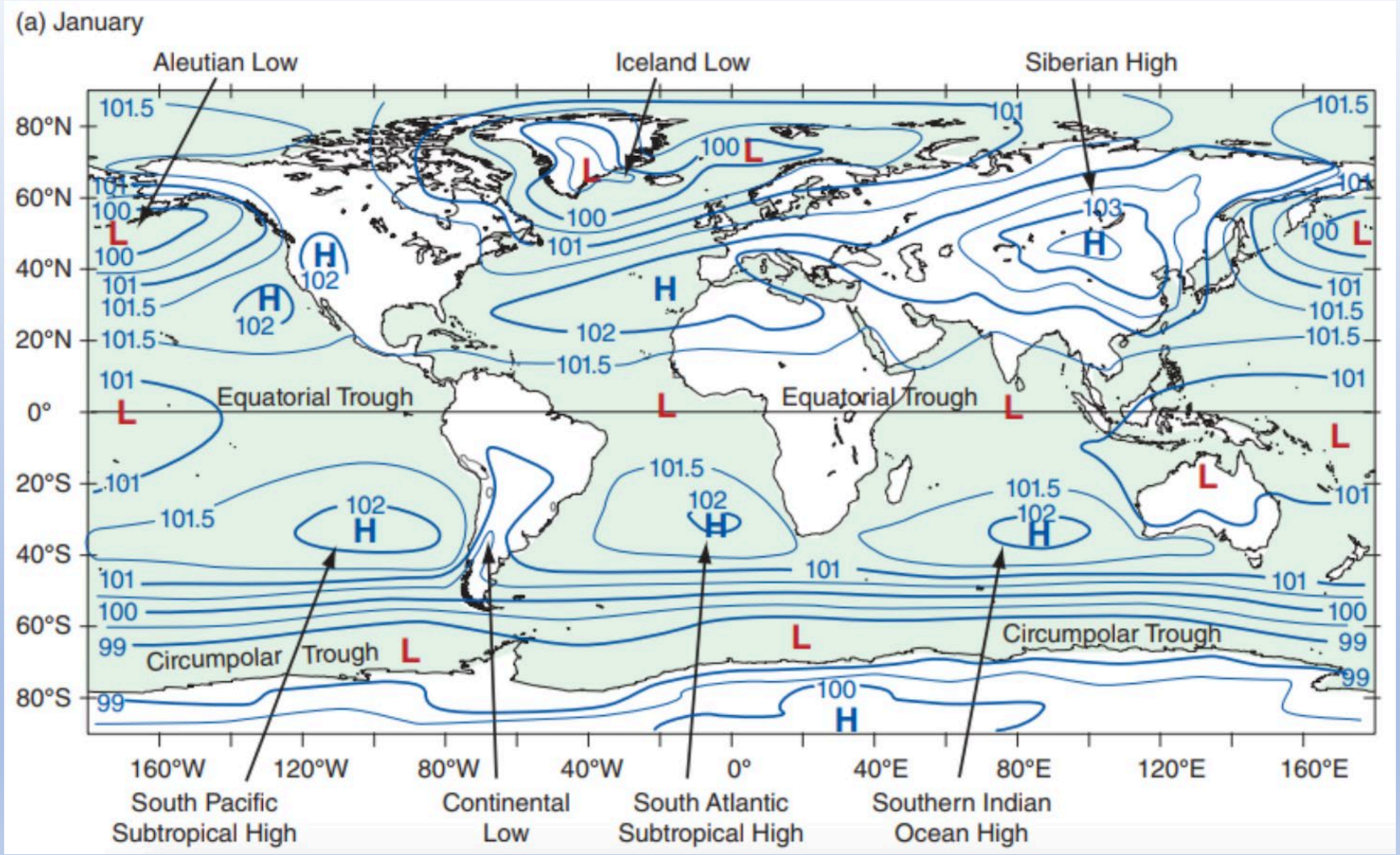
WIND !

Global Circulation with Coriolis Force

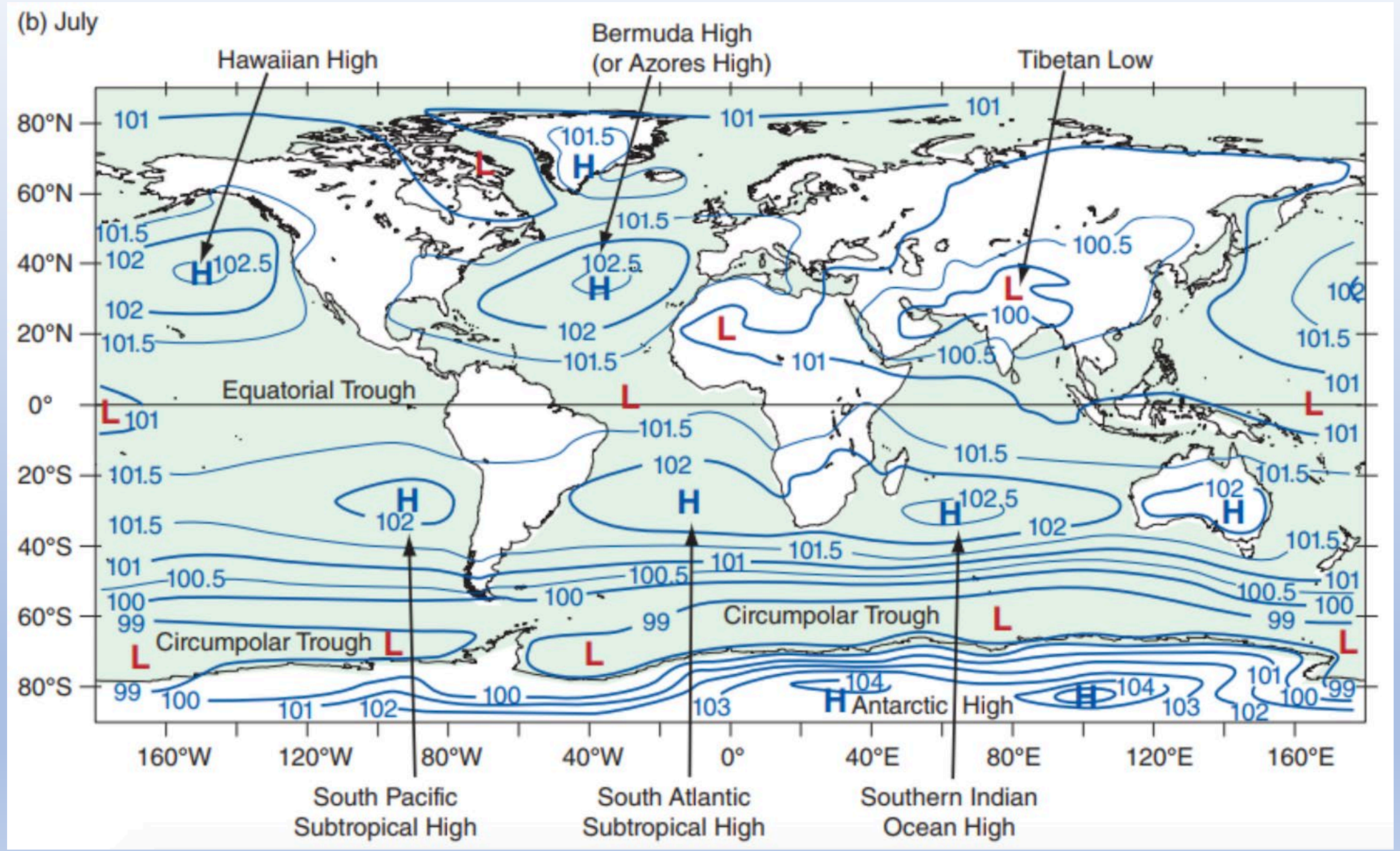
PJ Polar Jet
SJ Subtropical Jet



Global Pressure Pattern January



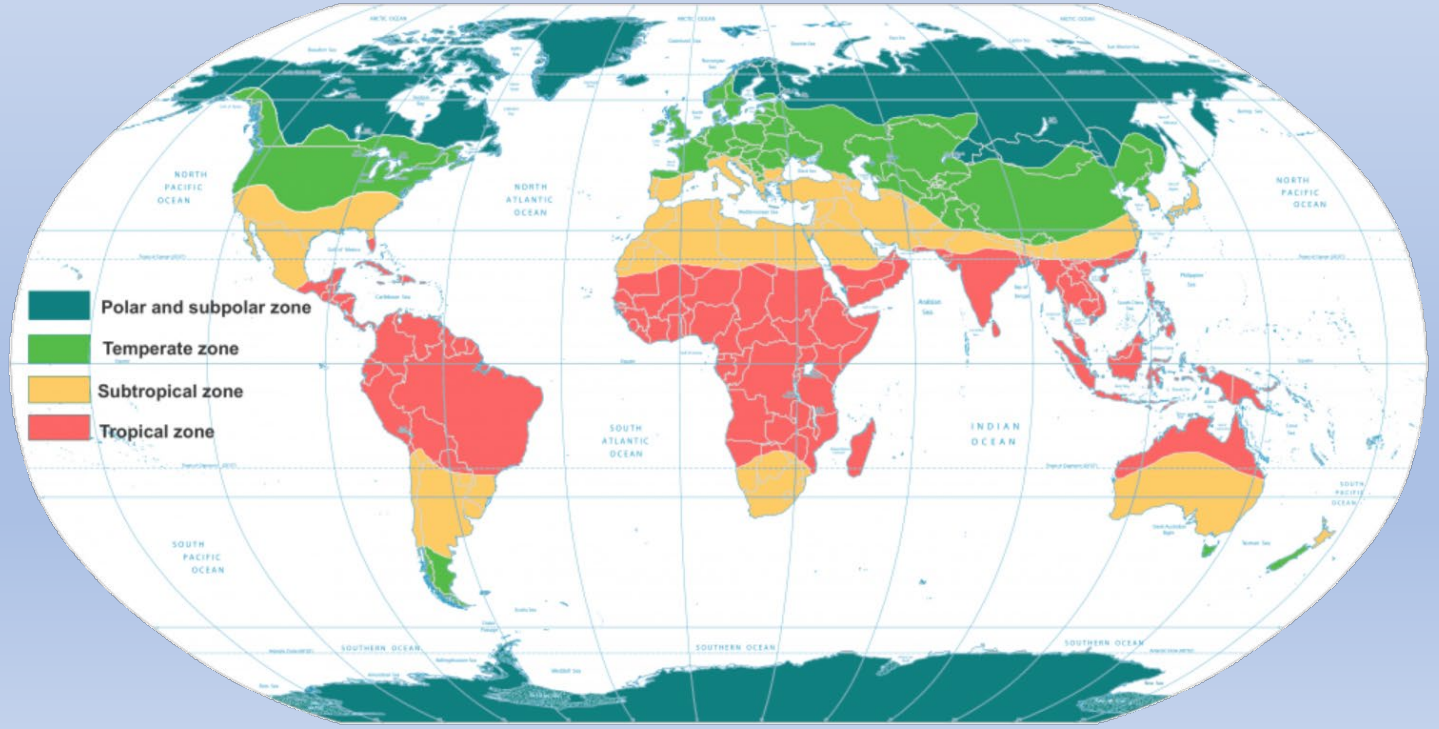
GLOBAL PRESSURE PATTERN JULY



Which Climate Regions are there ?

Tropics 0° – 23,5° Equator to Tropics of Cancer / Capricorn

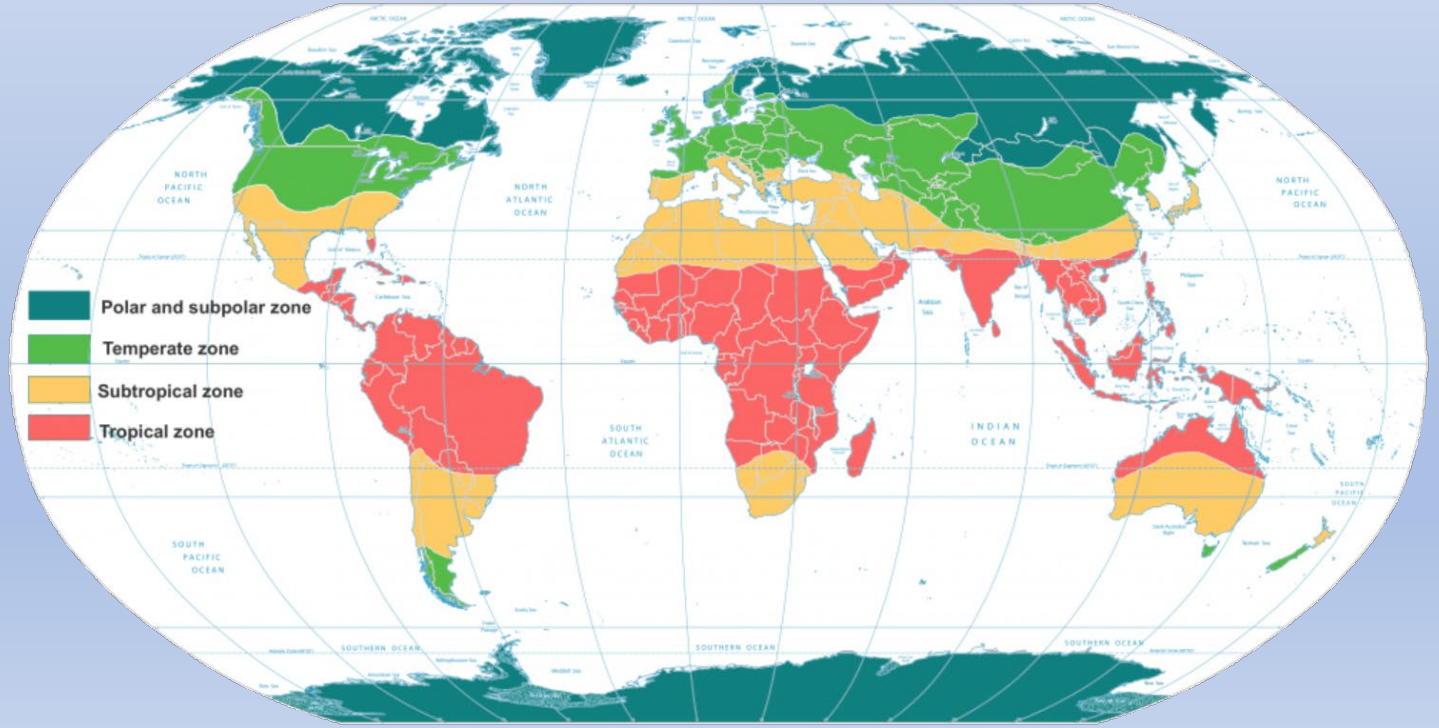
- Solar radiation almost from vertical all through the year
- Very warm/hot, high humidity,
- Typical Daily Variation (Convective clouds, Shower, Thunderstorm
- Almost no annual variation



Which Climate Regions are there ?

Subtropical 23,5° – 40°

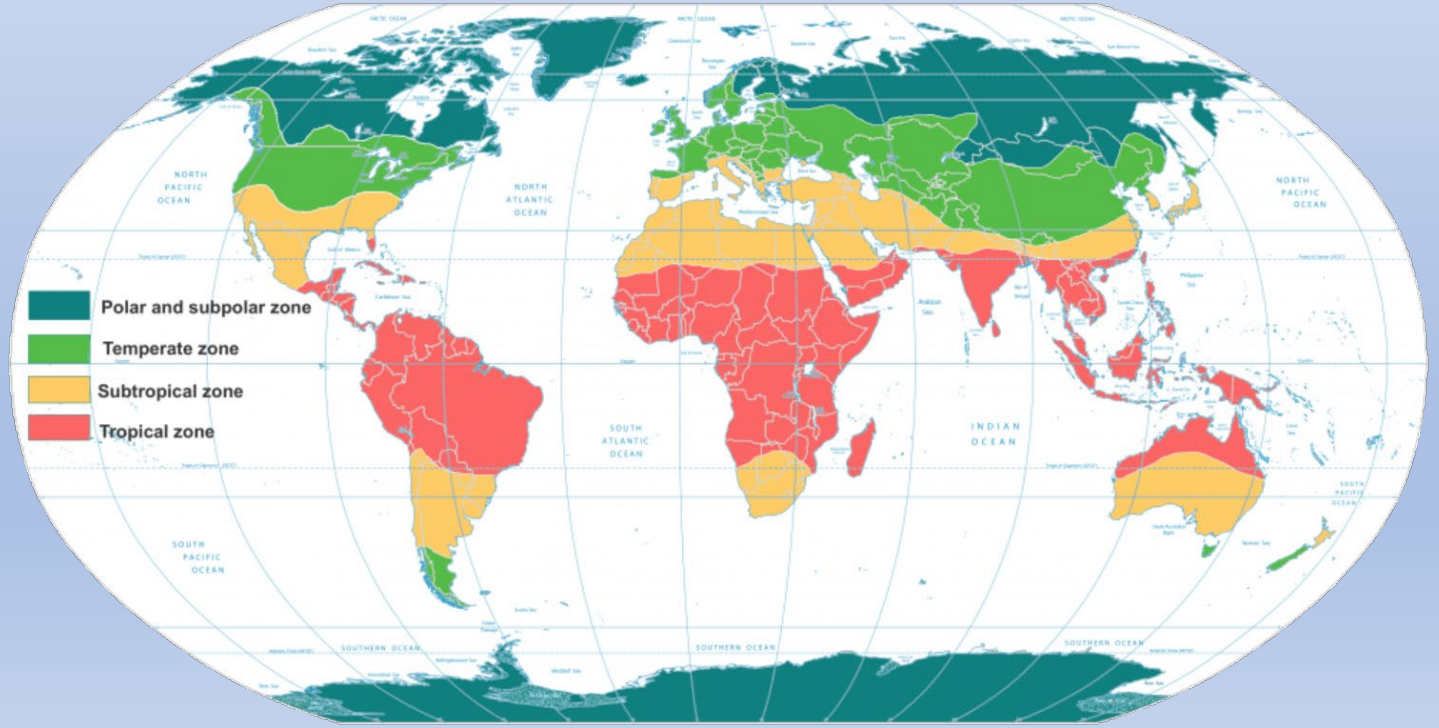
- Highest solar radiation in summer at high sun elevation
- Lower humidity results in less cloud cover
- Subtropical High (Acores), Trade winds. Deserts
- Significantly less Solar radiation in Winter,
- Winter season temporarily quite cold and moist



Which Climate Regions are there ?

Temperate zone 40° - 60°

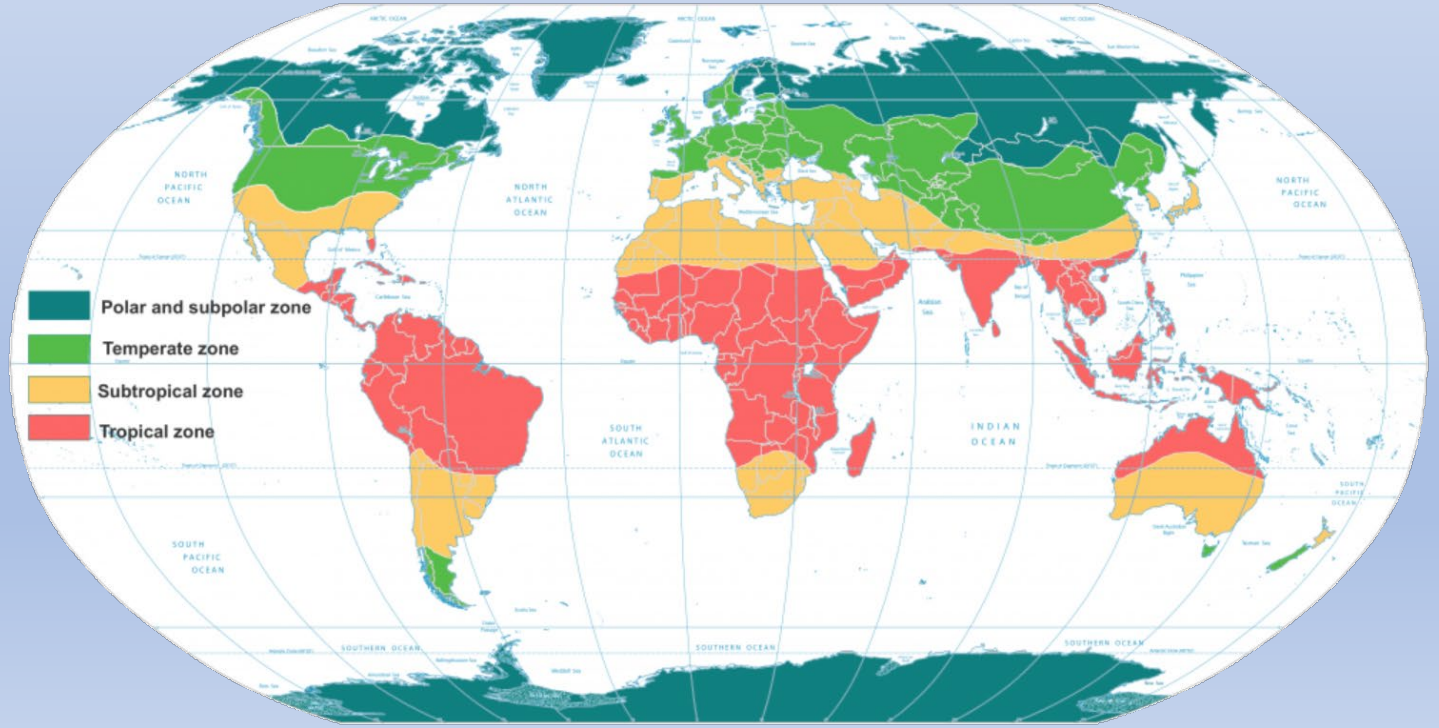
- Solar radiation arrives with a smaller angle, temperatures much lower
- Seasons and daylength differ significantly in the course of a year.
- Climate characterised by less frequent extremes,
- More regular distribution of precipitation over the year
- Longer vegetation period - therefore the name "temperate".



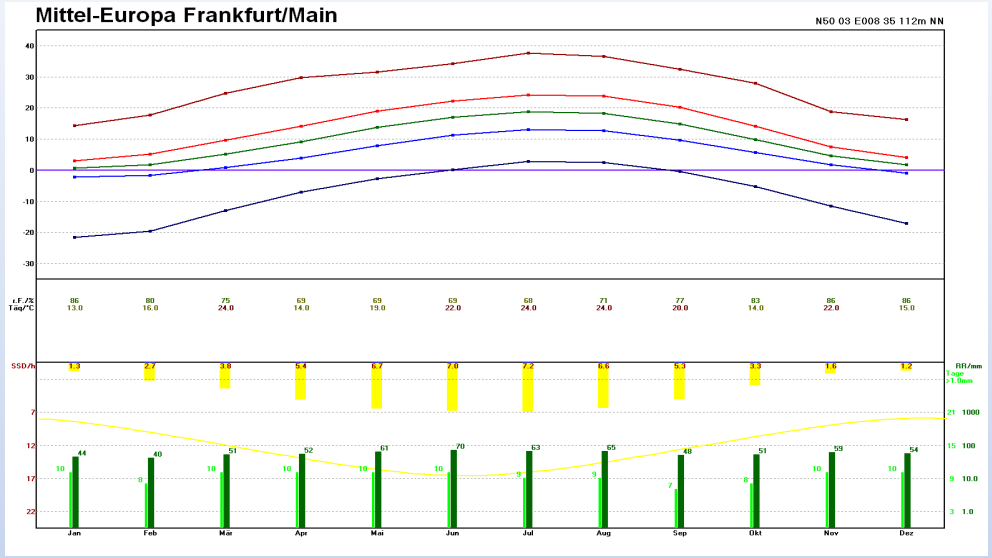
Which Climate Regions are there ?

Polar Regions 60° - 90°

- Polar areas receive less heat through solar radiation
- Sun at very flat angle toward the ground (slant Earth axis)
- daylength extreme: Polar Day and Polar Night
- In summer vegetation is only possible during a few months
- Very hard conditions for life in these regions

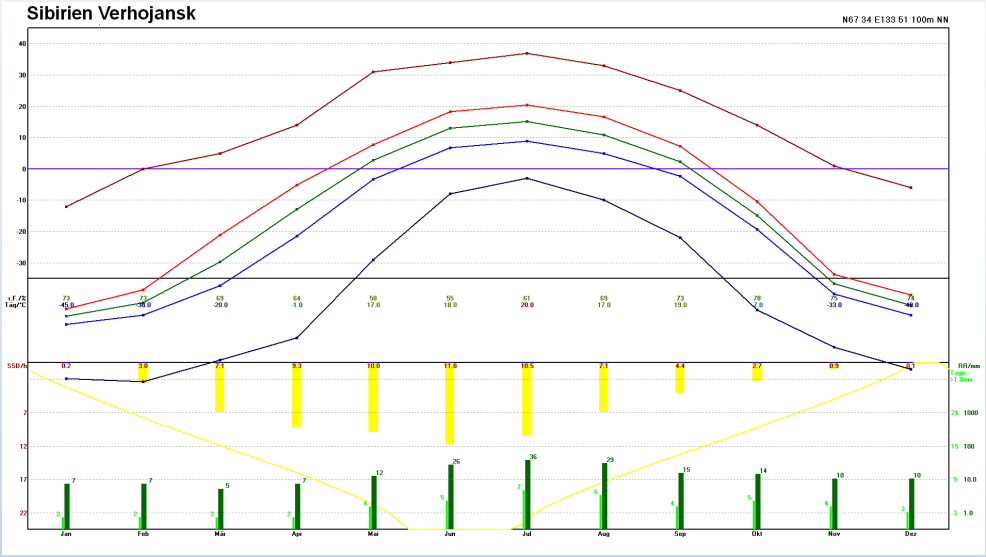


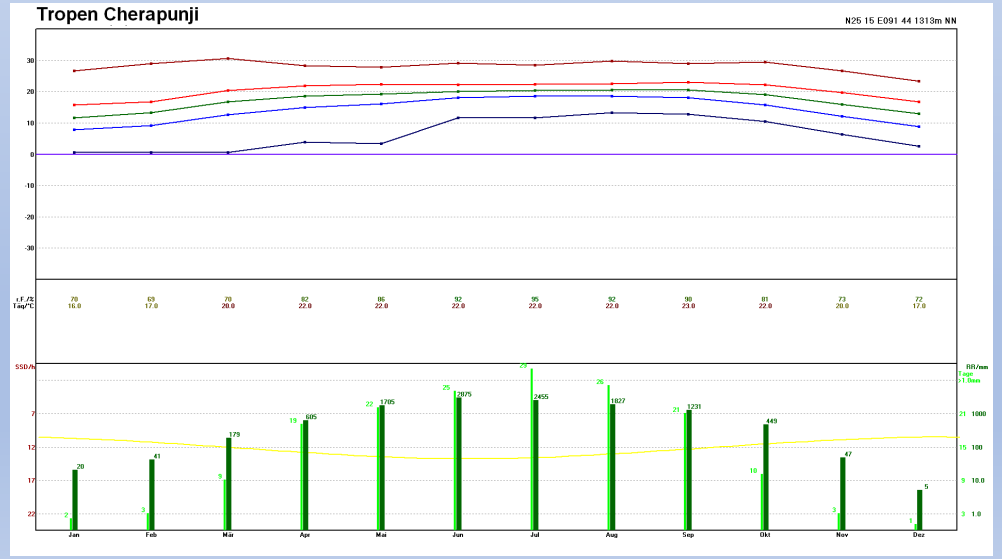
Annual Variation of meteorological parameters worldwide



T max, highest
T max, mean
T mean
T min, mean
T min, lowest

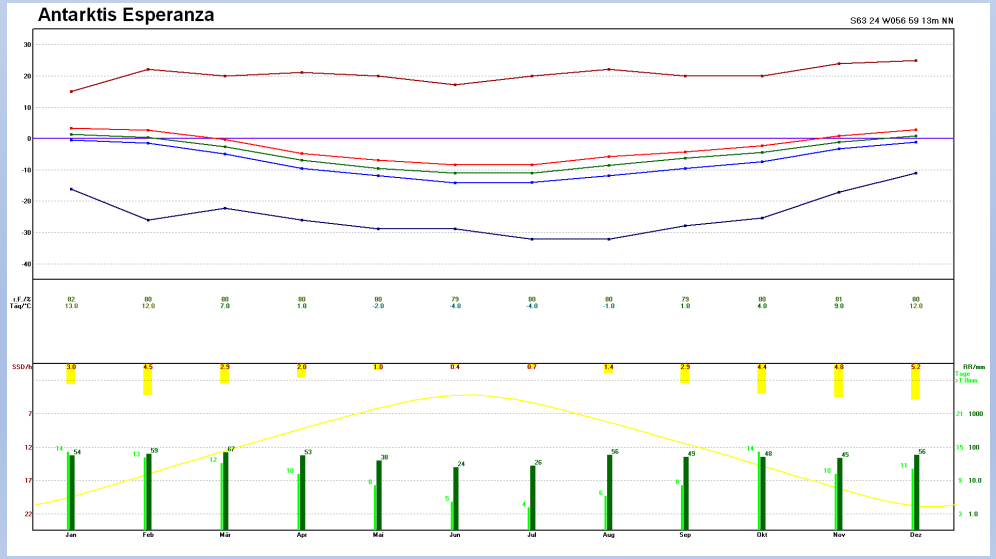
Duration of Sunshine
Precipitation amount
Days with RR >0.1mm

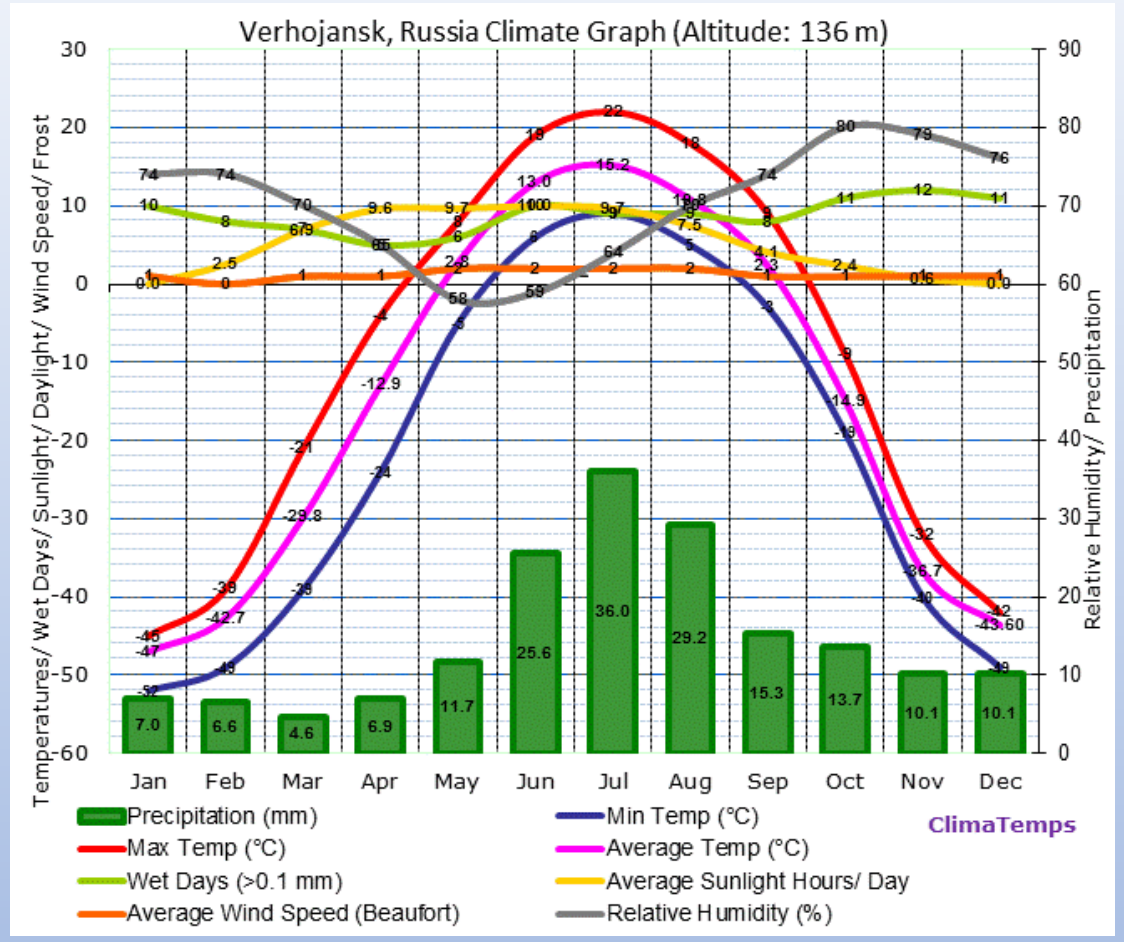




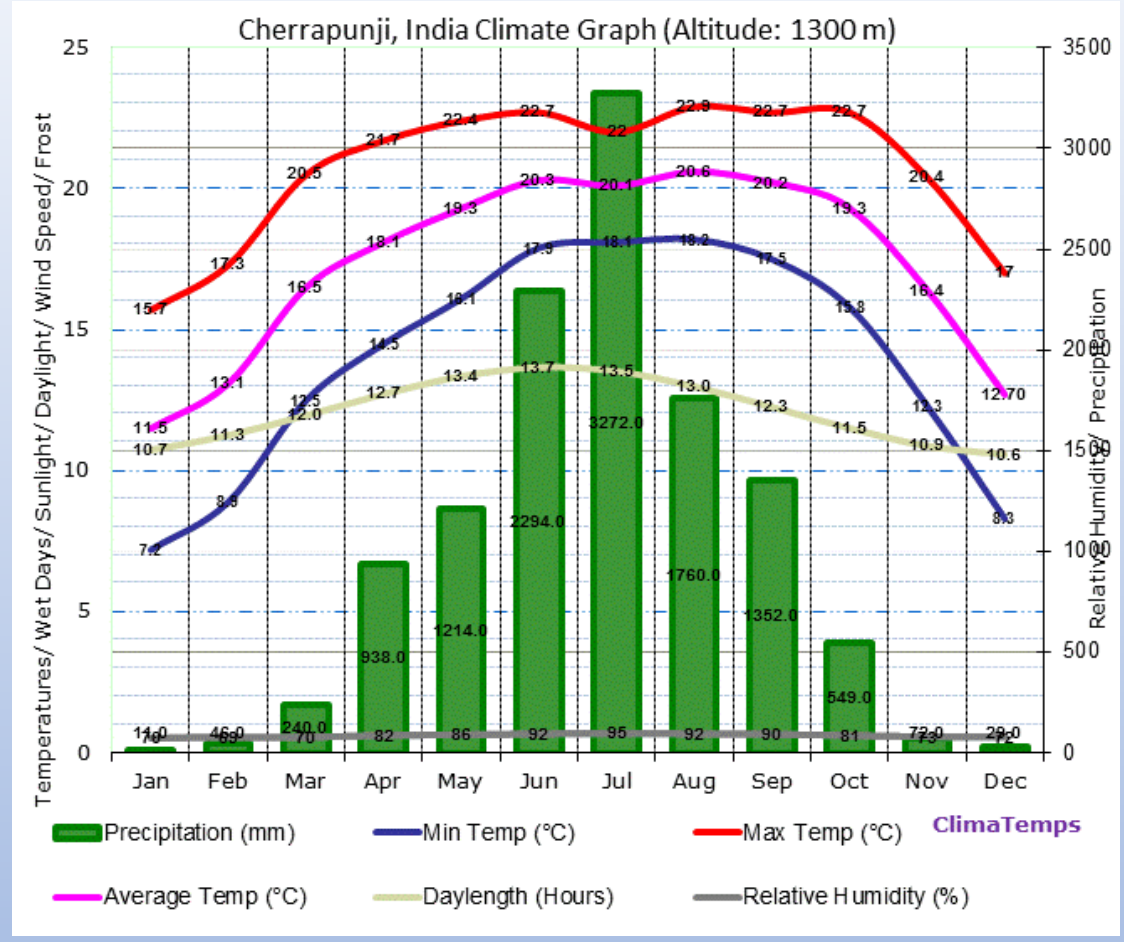
T max, highest
T max, mean
T mean
T min, mean
T min, lowest

Duration of Sunshine
Precipitation amount
Days with RR >0.1mm



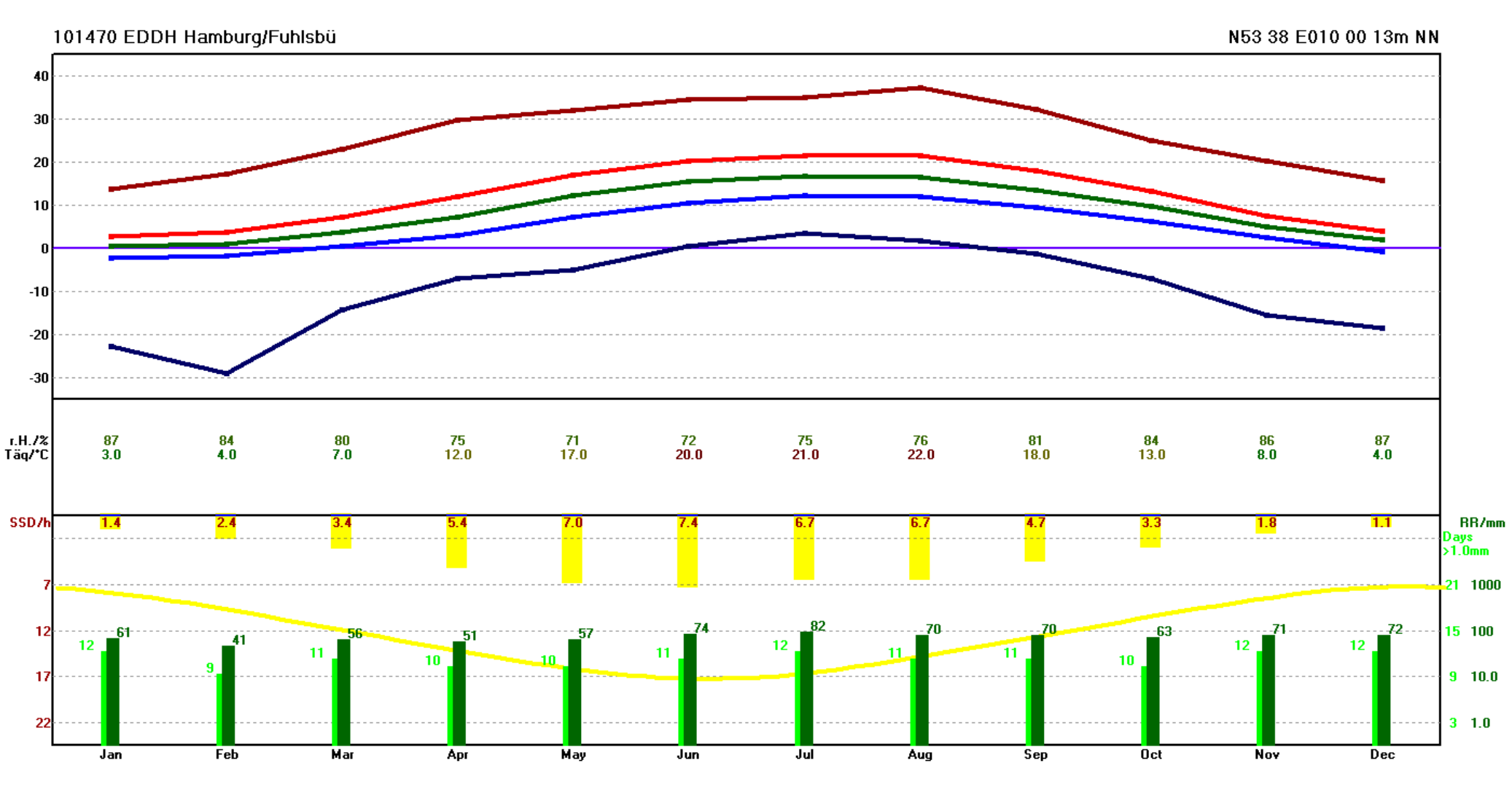


Annual variation of Polar station Verhoyansk
High Temperature-amplitude



Tropical station Cherrapunji
Low Temperature-amplitude

Annual Variation of Temperature Precipitation Sunshine Hamburg



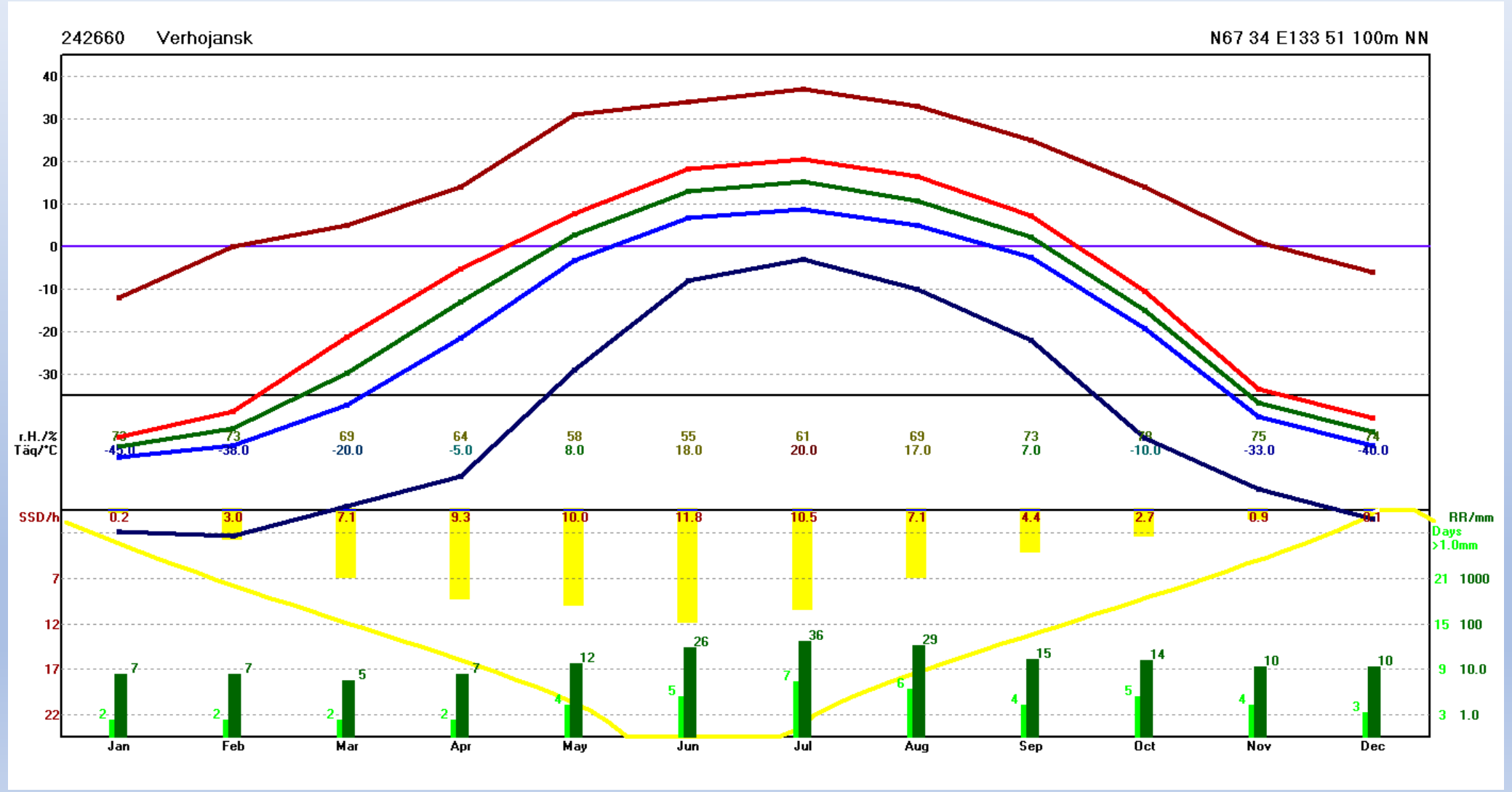
Annual Variation of Temperature Precipitation Sunshine Hamburg HAM

101470 EDDH Hamburg/Fuhlsbüttel N53 38 E010 00 13m NN

	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
absolute minimum	37.3	13.8	17.2	23.0	29.7	32.1	34.6	35.1	37.3	32.3	25.1	20.2	15.7
Average maximum	12.4	2.7	3.8	7.2	11.9	17.0	20.2	21.4	21.6	18.0	13.3	7.6	4.0
Monthly Mean	8.6	0.5	1.1	3.7	7.3	12.2	15.5	16.8	16.6	13.5	9.7	5.1	1.9
Average minimum	4.9	-2.2	-1.8	0.4	3.0	7.2	10.4	12.2	11.9	9.4	6.3	2.5	-0.7
absolute minimum	-29.1	-22.8	-29.1	-14.3	-7.1	-5.0	0.6	3.4	1.8	-1.2	-7.1	-15.4	-18.5
Relative humidity	80	87	84	80	75	71	72	75	76	81	84	86	87
Amount of precip	770	61	41	56	51	57	74	82	70	70	63	71	72
Days with precip	133	12	9	11	10	10	11	12	11	11	10	12	12
Dur.Sunshine /day	4.3	1.4	2.4	3.4	5.4	7.0	7.4	6.7	6.7	4.7	3.3	1.8	1.1
Dur.Sunshine abs.	1571	43	68	105	162	217	222	208	208	141	102	54	34

Temperate Region, moderate annual variation

Annual Variation of Temperature Precipitation Sunshine Verhojansk



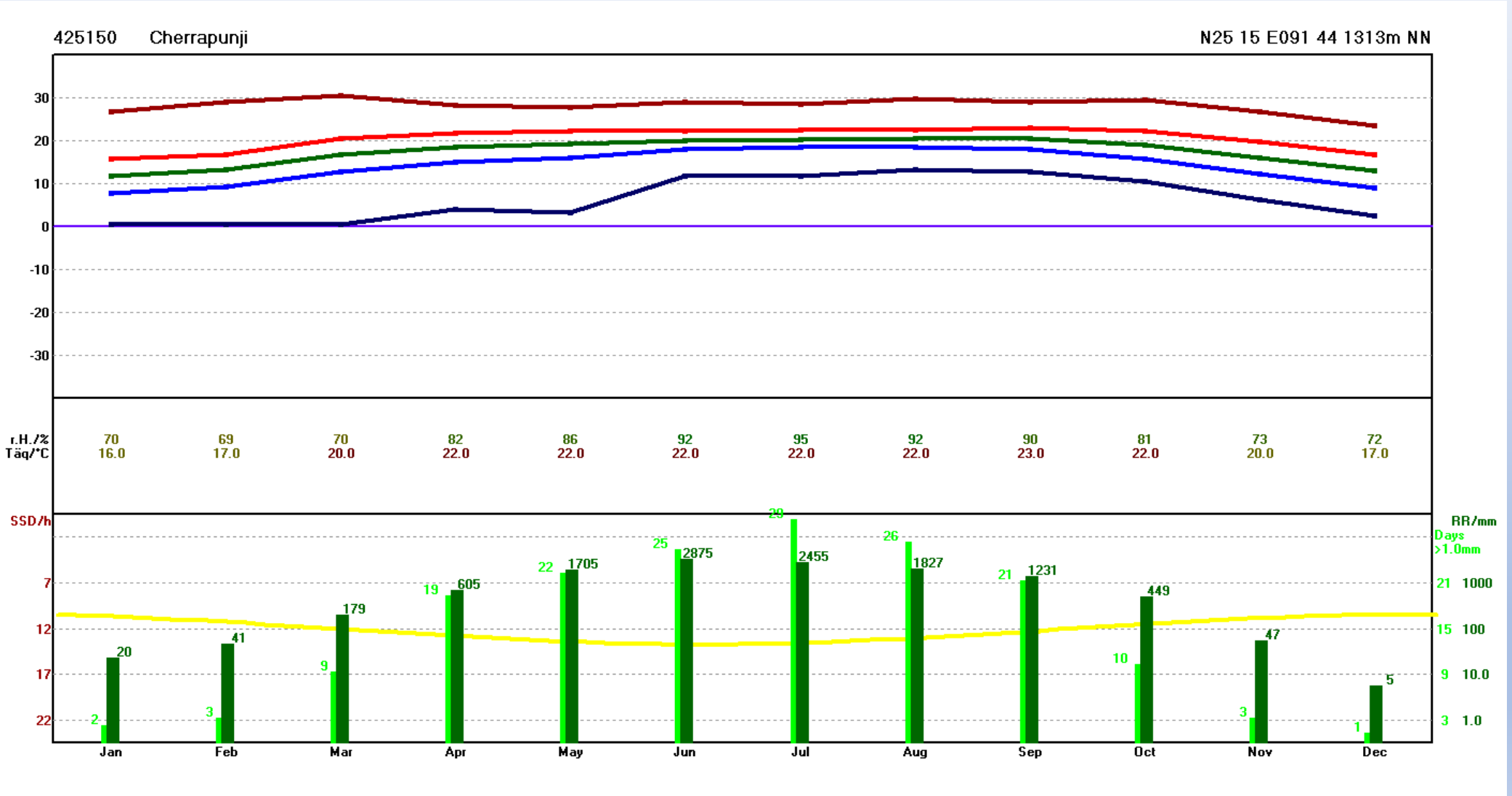
Annual Variation of Temperature Precipitation Sunshine Verhojansk RUS

242660 Verhojansk N67 34 E133 51 100m NN

		YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Highest	Maximum	37.0	-12.0	0.0	5.0	14.0	31.0	34.0	37.0	33.0	25.0	14.0	1.0	-6.0
Average	Maximum	-10.3	-44.7	-38.7	-21.2	-5.2	7.7	18.2	20.5	16.6	7.2	-10.4	-33.6	-40.3
Monthly	Mean	-15.3	-47.0	-42.7	-29.8	-12.9	2.8	13.0	15.2	10.8	2.3	-14.9	-36.7	-43.6
Average	Minimum	-20.5	-49.6	-46.7	-37.3	-21.5	-3.3	6.7	8.8	4.9	-2.4	-19.3	-39.9	-46.7
Lowest	Minimum	-68.0	-67.0	-68.0	-61.0	-54.0	-29.0	-8.0	-3.0	-10.0	-22.0	-45.0	-57.0	-64.0
Relative humidity		68	73	73	69	64	58	55	61	69	73	78	75	74
Amount of precip		178	7	7	5	7	12	26	36	29	15	14	10	10
Days with precip		46	2	2	2	2	4	5	7	6	4	5	4	3
Dur.Sunshine /day		5.6	0.2	3.0	7.1	9.3	10.0	11.8	10.5	7.1	4.4	2.7	0.9	0.1
Dur.Sunshine abs.		2045	6	85	220	279	310	354	326	220	132	84	27	3

Polar Region, extreme annual variation

Annual Variation of Temperature Precipitation Sunshine Cherrapunji



Annual Variation of Temperature Precipitation Sunshine Cherrapunji IND

425150 Cherrapunji N25 15 E091 44 1313m NN

		YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Highest	Maximum	30.6	26.7	28.9	30.6	28.3	27.8	29.1	28.4	29.8	28.9	29.4	26.7	23.4
Average	Maximum	20.5	15.8	16.8	20.4	21.8	22.3	22.2	22.4	22.5	23.0	22.2	19.7	16.8
Monthly	Mean	17.4	11.7	13.3	16.7	18.6	19.2	20.0	20.3	20.5	20.5	19.1	15.9	12.9
Average	Minimum	14.2	7.8	9.2	12.7	14.9	16.1	18.0	18.5	18.5	18.1	15.8	12.2	8.9
Lowest	Minimum	0.6	0.6	0.6	0.6	3.9	3.3	11.7	11.7	13.3	12.8	10.5	6.3	2.5
Relative humidity		70	69	70	82	86	92	95	92	90	81	73	72	
Amount of precip		11439	170	20	41	179	605	1705	2875	2455	1827	1231	449	47
Days with precip		81	2	3	9	19	22	25	29	26	21	10	3	1

(Sub-)Tropical Region, almost no annual variation, extreme precipitation amount

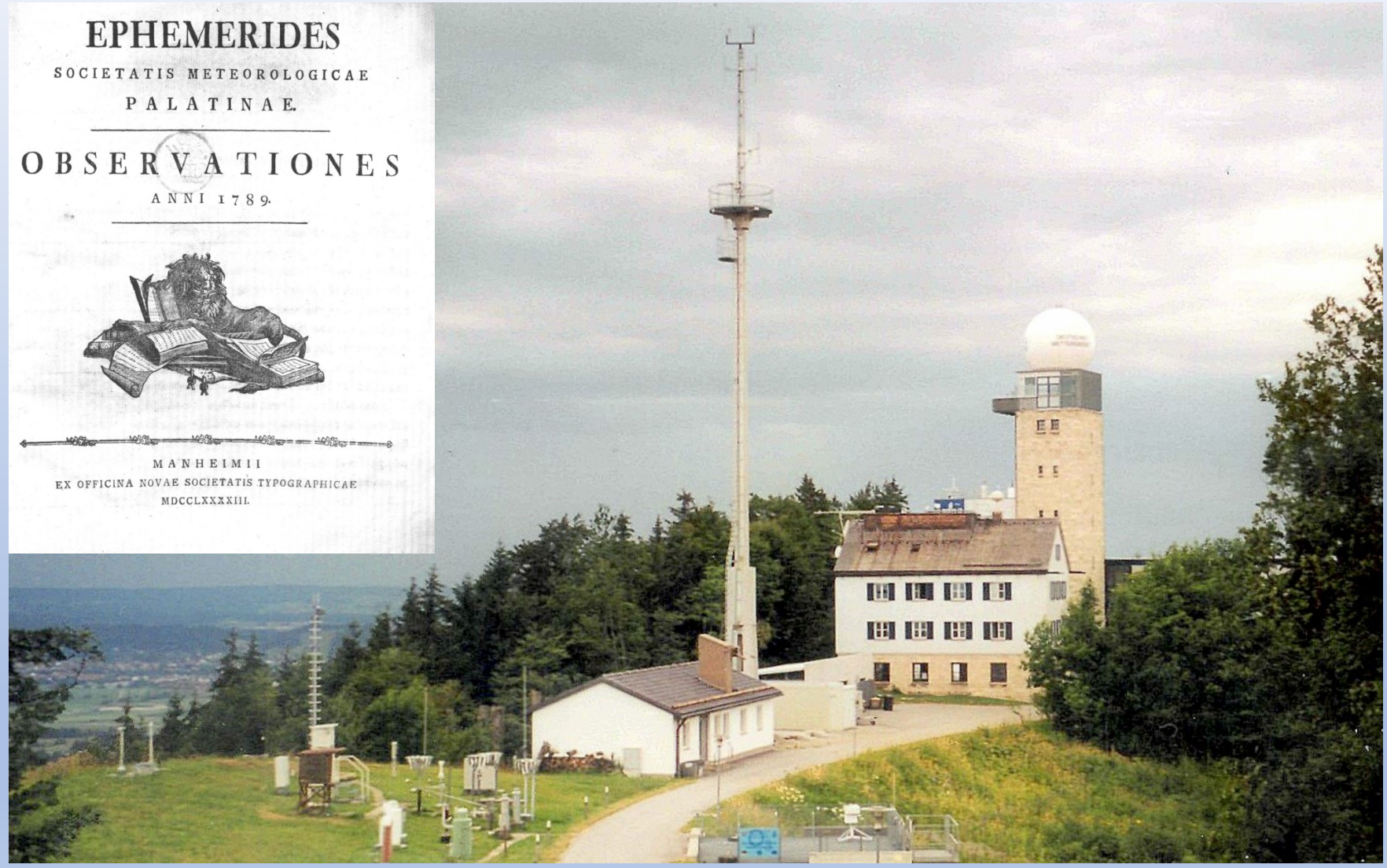
How to get climate data? Weather Observations

Weather observations (measurements) started

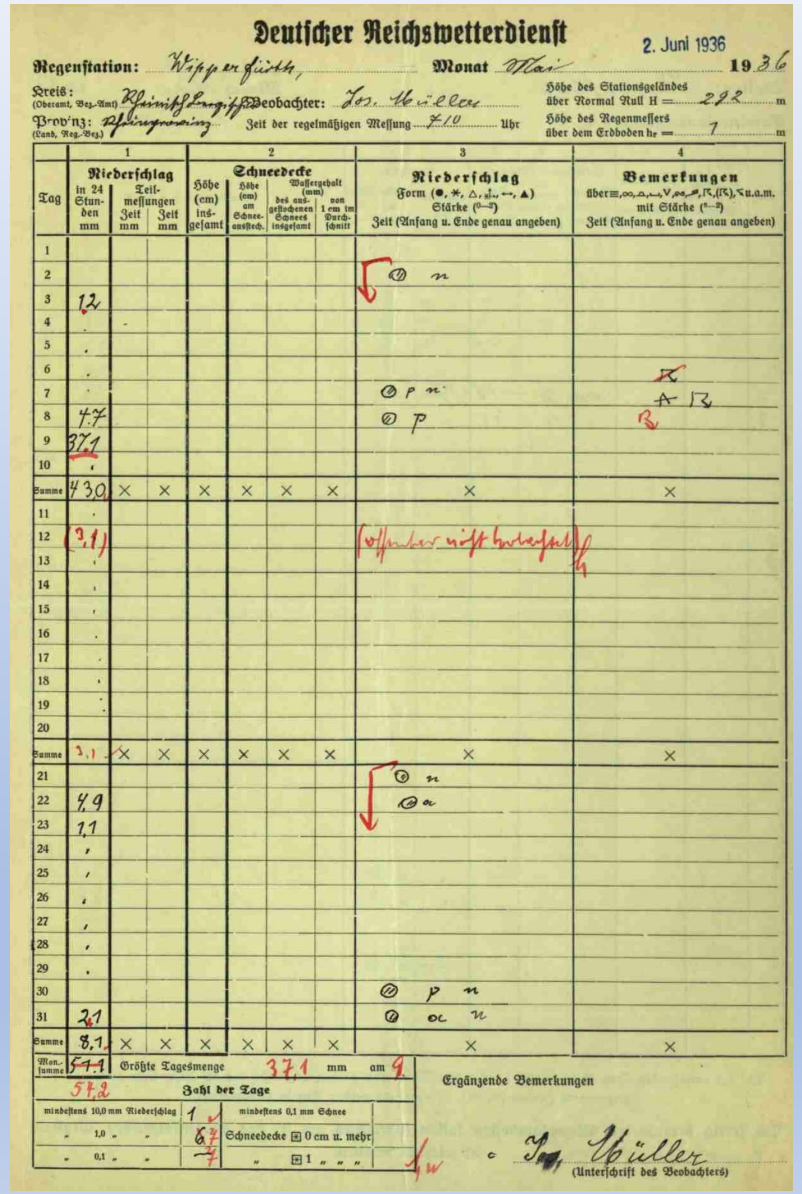
➢ Temperatur	1659 Central-England
➢ Precipitation	1697 Kew (London)
➢ Pressure	1740 De Bilt
➢ Wind	1781 Hohenpeissenberg
➢ Duration of Sunshine	1880 Kew (London)
➢ Snow Depth	1881 Vienna

➢ Global datasets since 1850

How to get climate data?



How to get climate data? Weather Diaries 1936, 1996



Deutscher Reichswetterdienst

2. Juni 1936

Regenstation: Wipperfürth, Monat Mai 1936

Kreis: (Oberamt, Bez.-Amt) Rheinisch-Bergischer Beobachter: Joz. Müller

Provinz: (Land, Reg.-Bez.) Rheinprovinz Zeit der regelmäßigen Messung 7:10 Uhr

Höhe des Stationsgeländes über Normal Null H = 222 m

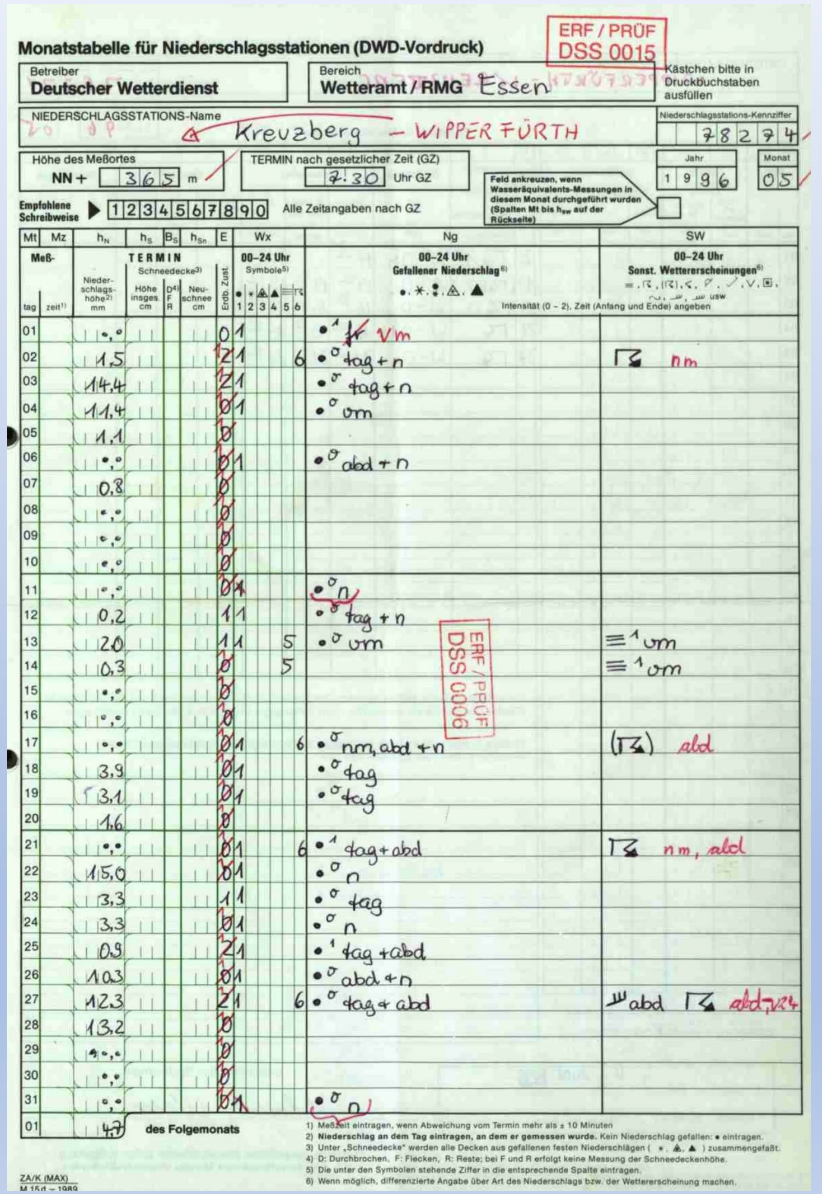
Höhe des Regenmessers über dem Erdboden h_r = 1 m

Tag	1 Niederschlag in 24 Stunden mm	Teilmessungen Zeit	Teilmessungen mm	2 Schneedecke Höhe (cm) insgesamt	Höhe (cm) am Schneeaustech.	Wassergehalt (mm) des ausgefallenen Schnees insgesamt	Wassergehalt (mm) von 1 cm im Durchschnitt	3 Niederschlag Form (●, *, △, ≋, ↔, ▲) Stärke (0–5) Zeit (Anfang u. Ende genau angeben)	4 Bemerkungen über ≡, ∞, ⌓, ⌒, V, ⌓, ⌓, ⌓, [R], [R], ≤ u.a.m. mit Stärke (0–5) Zeit (Anfang u. Ende genau angeben)
1									
2								① n	
3	12								
4	.								
5	.								
6	.								
7	.							② p n	
8	4.7							② p	
9	37.1								
10	,								
Summe	43,0	×	×	×	×	×	×	×	×
11	.								
12	(3,1)							(offenbar nicht beobachtet)	
13	,								
14	,								
15	,								
16	.								
17	.								
18	,								
19	.								
20									
Summe	3,1	×	×	×	×	×	×	×	×
21								① n	
22	4,9							② a	
23	1,1								
24	,								
25	,								
26	,								
27	,								
28	,								
29	.								
30								② p n	
31	2,1							② oc n	
Summe	8,1	×	×	×	×	×	×	×	×
Monatssumme	54,1	Größte Tagesmenge		37,1 mm		am 9			
	54,2	Zahl der Tage							
mindestens 10,0 mm Niederschlag		1		mindestens 0,1 mm Schnee					
„ 1,0 „ „		6		Schneedecke ⊡ 0 cm u. mehr					
„ 0,1 „ „		7		„ ⊡ 1 „ „ „					

Ergänzende Bemerkungen

J. Müller

(Unterschrift des Beobachters)



Monatstabelle für Niederschlagsstationen (DWD-Vordruck)

ERF / PRÜF DSS 0015

Betreiber: Deutscher Wetterdienst

Bereich: Wetteramt / RMG Essen

Kästchen bitte in Druckbuchstaben ausfüllen

NIEDERSCHLAGSSTATIONS-Name: Kreuzberg – WIPPERFÜRTH

Niederschlagsstations-Kennziffer: 7827 4

Höhe des Meßortes NN + 365 m

TERMIN nach gesetzlicher Zeit (GZ): 7:30 Uhr GZ

Jahr: 1996 Monat: 05

Empfohlene Schreibweise: 1 2 3 4 5 6 7 8 9 0 Alle Zeitangaben nach GZ

Feld ankreuzen, wenn Wasseräquivalents-Messungen in diesem Monat durchgeführt wurden (Spalten Mt bis h_{SH} auf der Rückseite)

Mt	Mz	h_N	h_S	B_S	h_{Sn}	E	Wx	Ng	SW
Meß- tag	zeit[1]	TERMIN Niederschlagshöhe[2] mm	Schneedecke[3] Höhe insges. cm	D[4] F R	Neuschnee cm	Erdb. Zust.	00–24 Uhr Symbole[5] ● * ▲ ▲ 1 2 3 4 5 6	00–24 Uhr Gefallener Niederschlag[6] Intensität (0 – 2), Zeit (Anfang und Ende) angeben	00–24 Uhr Sonst. Wettererscheinungen[6] ≡, [R], [R], ≤, ∞, V, ⊡, usw
01		•,°				0	1	•¹ fr vm	
02		1,5				2	1 6	•° tag + n	nm
03		14,4				2	1	•° tag + n	
04		11,4				0	1	•° vm	
05		1,1				0			
06		•,°				0	1	•° abd + n	
07		0,8				0			
08		•,°				0			
09		•,°				0			
10		•,°				0			
11		•,°				0	1	•° n	
12		0,2				1	1	•° tag + n	
13		2,0				1	1 5	•° vm	≡¹ vm
14		0,3				0	5		≡¹ vm
15		•,°				0			
16		•,°				0			
17		•,°				0	1 6	•° nm, abd + n	(⌓) abd
18		3,9				0	1	•° tag	
19		3,1				0	1	•° tag	
20		1,6				0			
21		•,°				0	1 6	•¹ tag + abd	⌓ nm, abd
22		15,0				0	1	•° n	
23		3,3				1	1	•° tag	
24		3,3				0	1	•° n	
25		0,9				2	1	•¹ tag + abd	
26		10,3				0	1	•° abd + n	
27		12,3				2	1 6	•° tag + abd	≡abd ⌓ abd, nm
28		13,2				0			
29		•,•,•				0			
30		•,°				0			
31		•,°				0	1	•° n	
01		47	des Folgemonats						

ERF / PRÜF DSS 0006

1) Meßzeit eintragen, wenn Abweichung vom Termin mehr als ± 10 Minuten

2) **Niederschlag an dem Tag eintragen, an dem er gemessen wurde.** Kein Niederschlag gefallen: • eintragen.

3) Unter „Schneedecke" werden alle Decken aus gefallenen festen Niederschlägen (* ▲ ▲) zusammengefaßt.

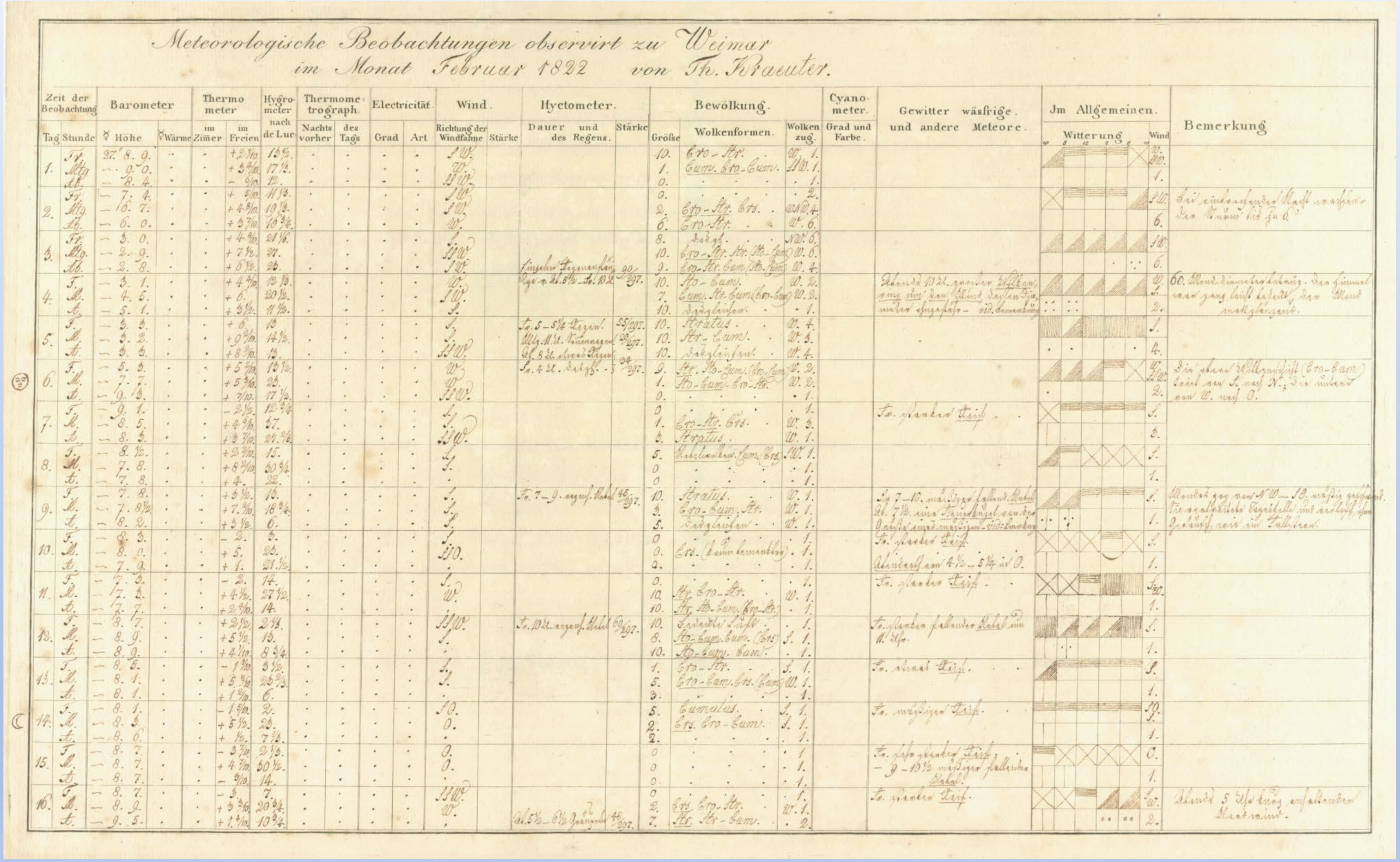
4) D: Durchbrochen. F: Flecken, R: Reste; bei F und R erfolgt keine Messung der Schneedeckenhöhe.

5) Die unter den Symbolen stehende Ziffer in die entsprechende Spalte eintragen.

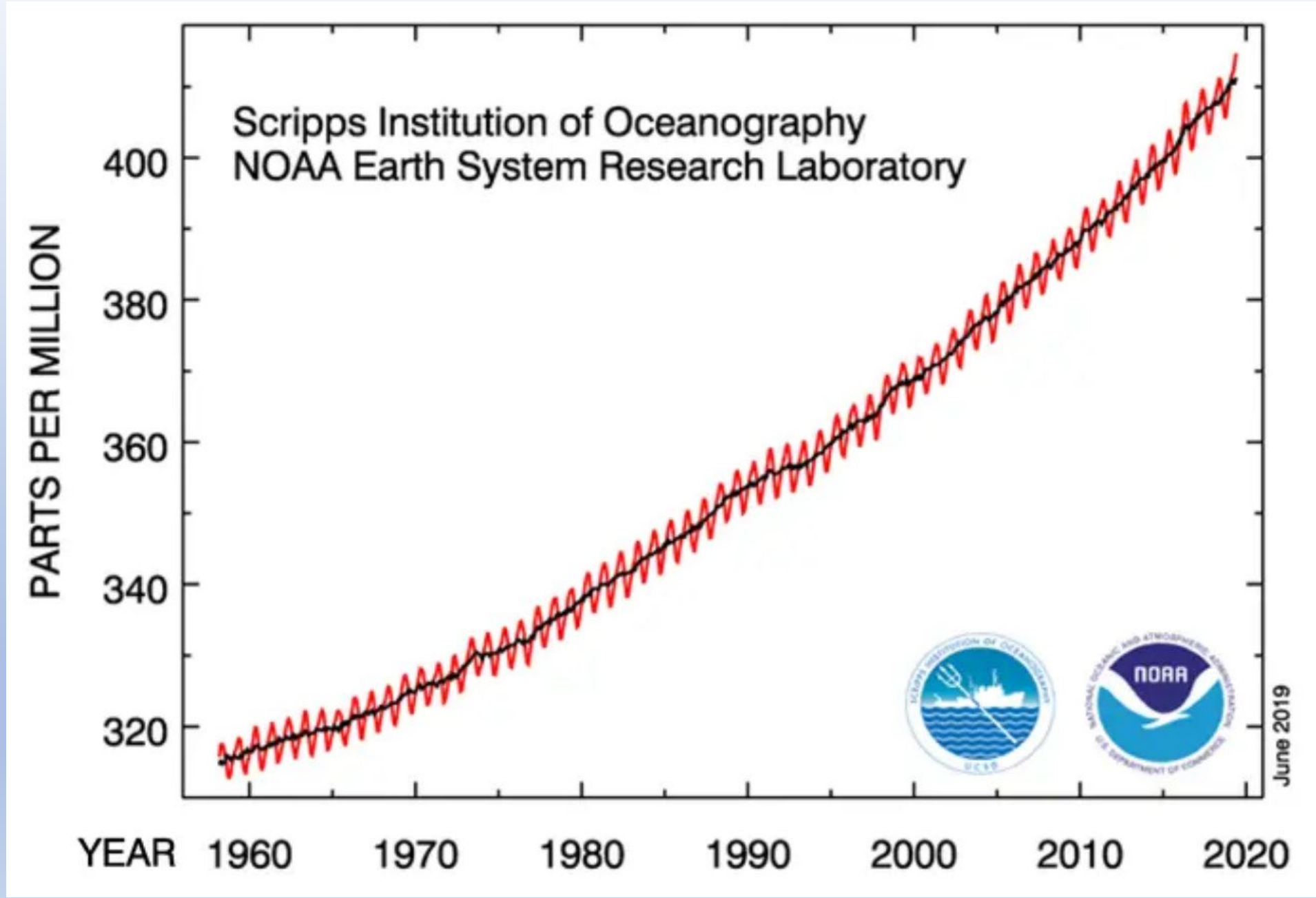
6) Wenn möglich, differenzierte Angabe über Art des Niederschlags bzw. der Wettererscheinung machen.

ZA/K (MAX) M 15d – 1986

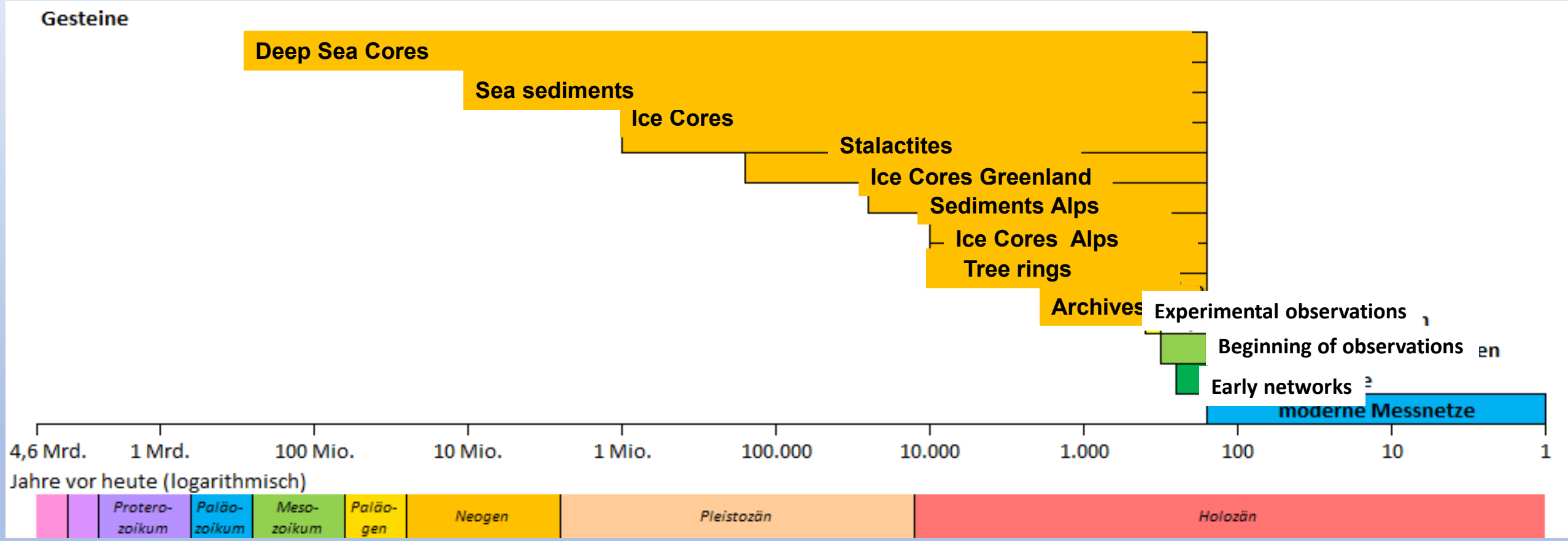
How to get climate data? Weather Observations 1822



How to get climate data ? CO2 Mauna Loa Hawaii



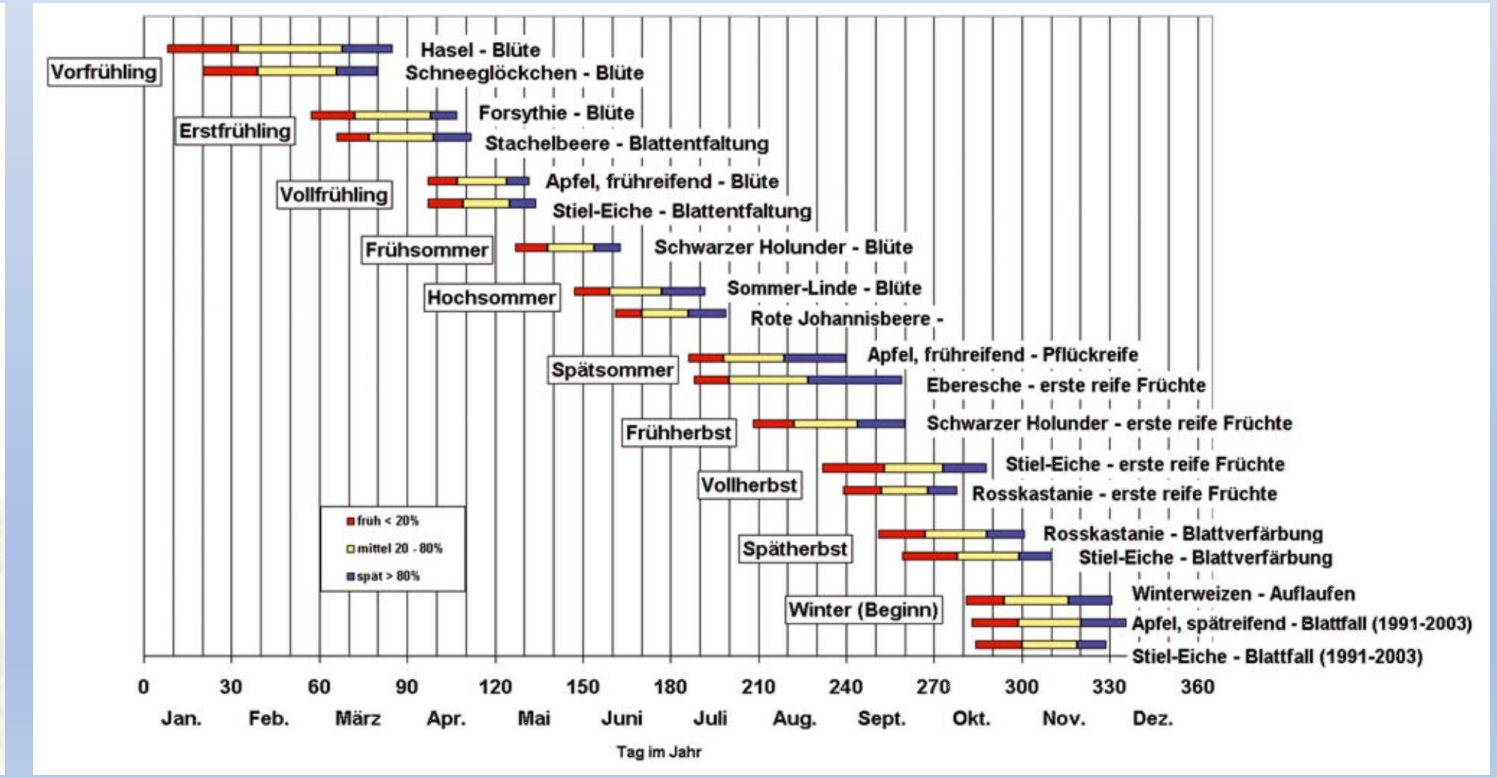
How to get climate data? Proxydata

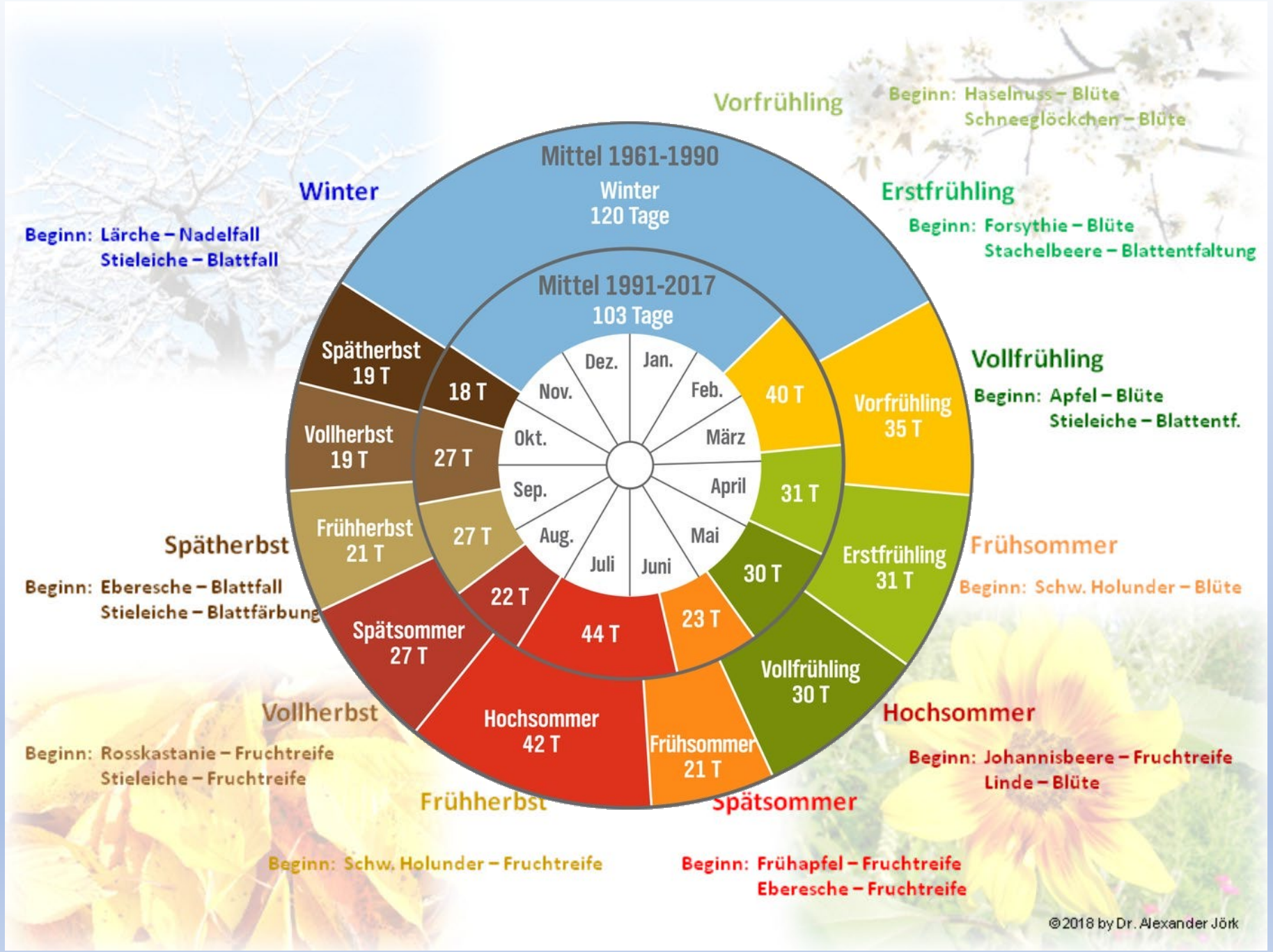


How to get climate data ? Phenological Observations

Proxydata (indirect data)

- Phenology: Observation of vegetation periods)





Global Change and Phenology

The phases of bloom for various trees / flower / fruits start earlier in the year

Comparison

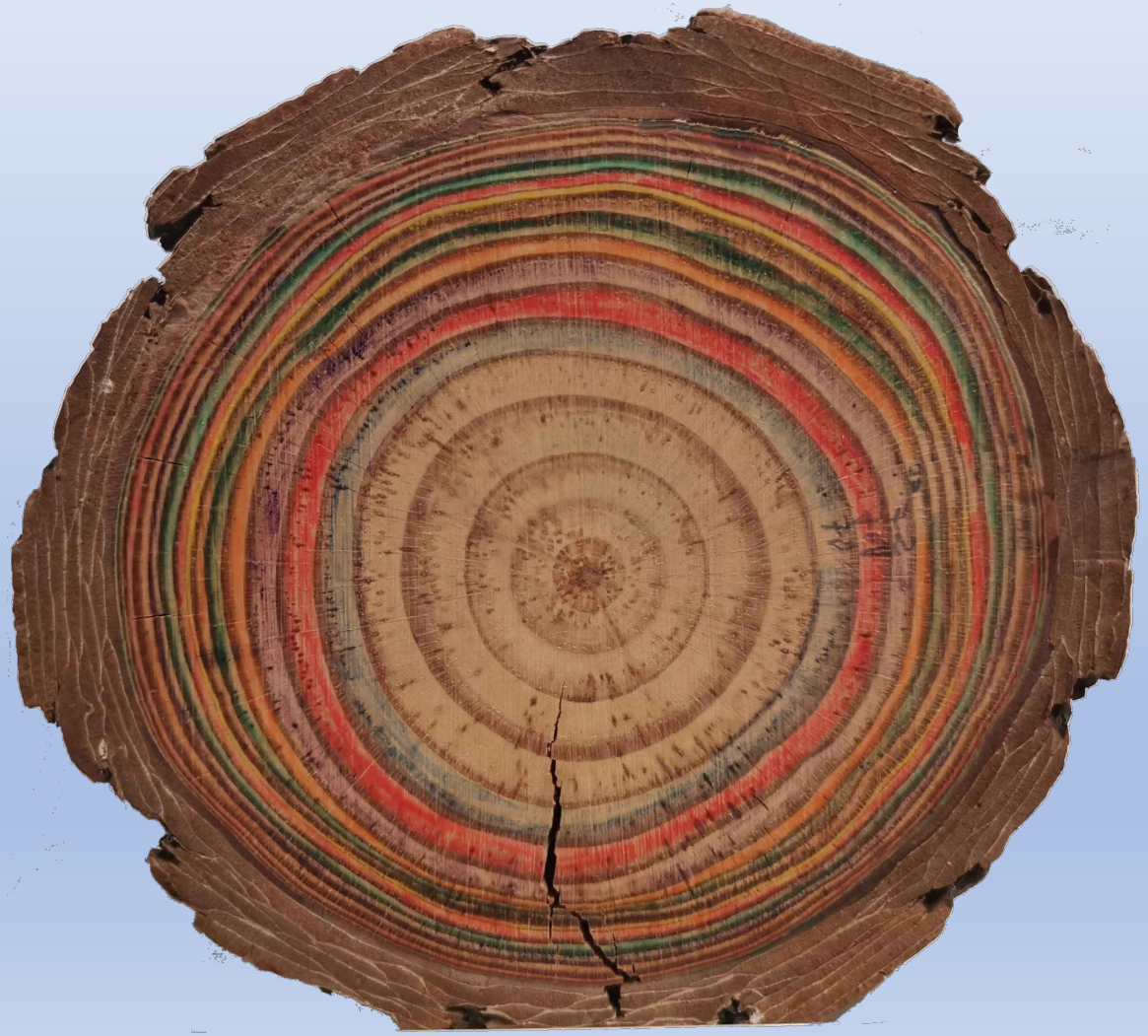
1961-1990 vs 1991-2017

The winter lasts
103 days instead of 120 days

How to get climate data ? Dendrochronology

Proxydata (indirect data, not measured itself)

- Tree rings (Dendrochronology)

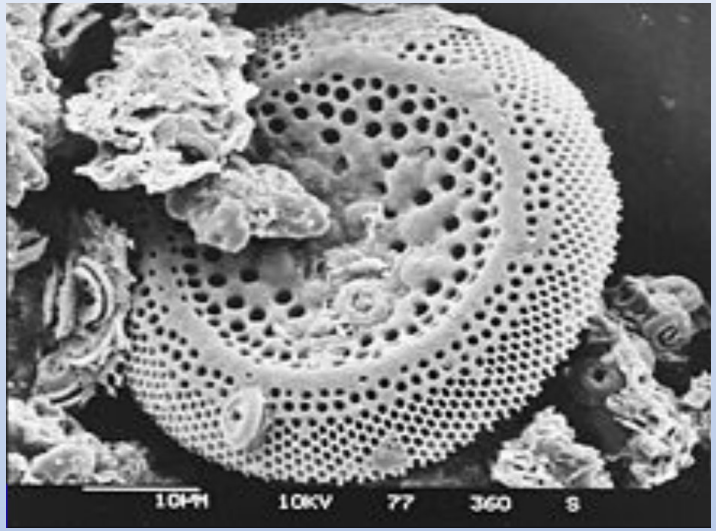


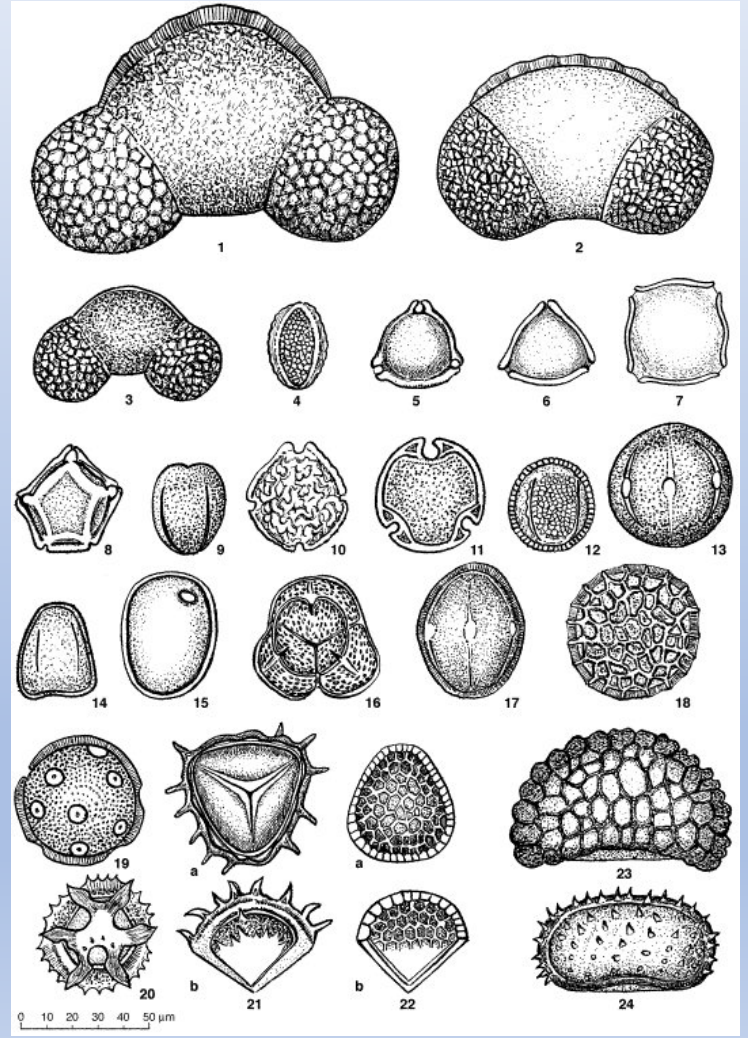
Spessarteiche Würzburg - Weingut Juliusspital, Jahresringe von 1545 bis 1991

How to get climate data ? Proxydata Pollen, Foraminifera

Proxydata (indirect data)

- Foraminifera, Pollenanalysis





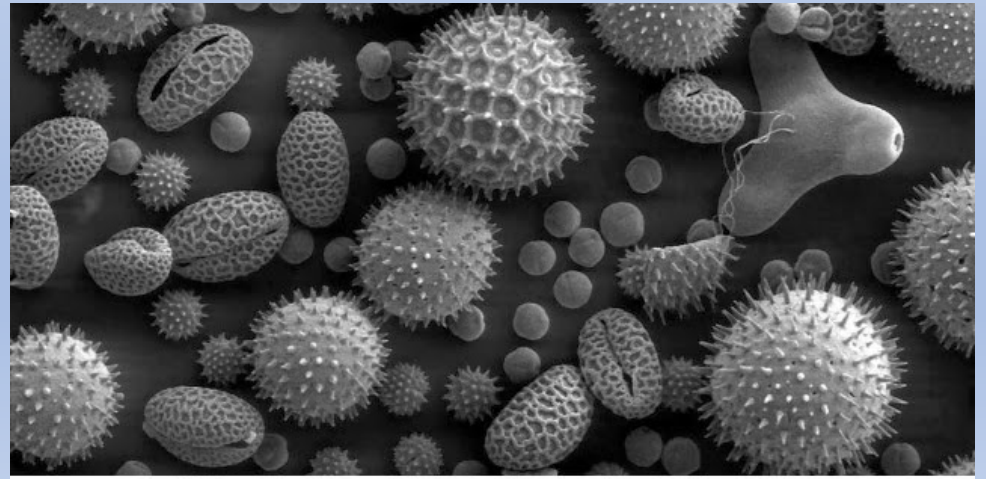
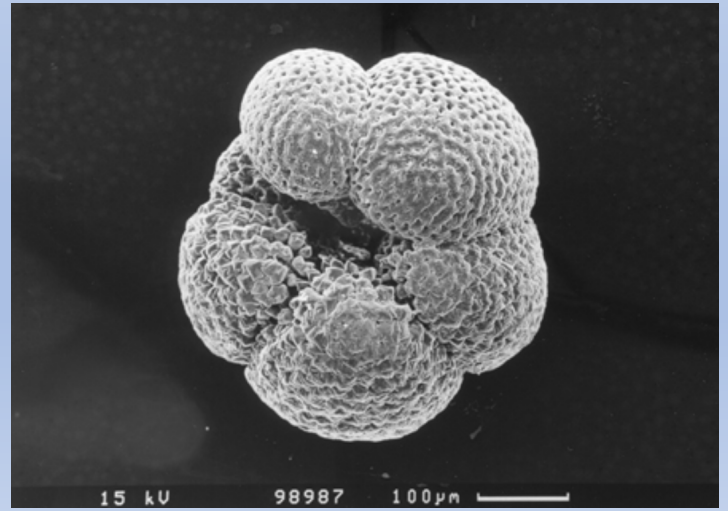


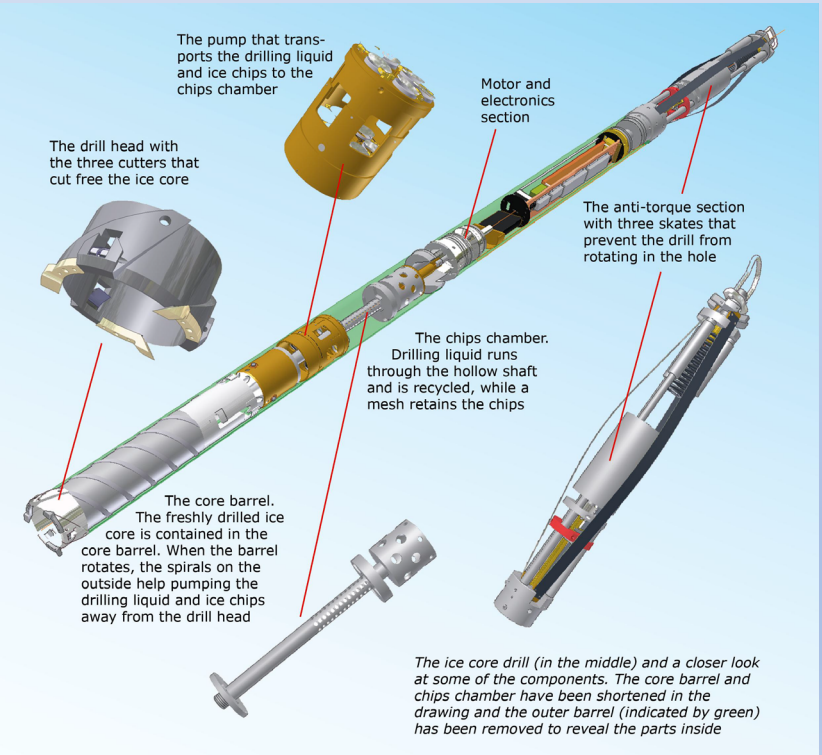
Foto: Verschiedene Arten von Pollen | Quelle: Wikimedia.org | Urheber: Dartmouth College



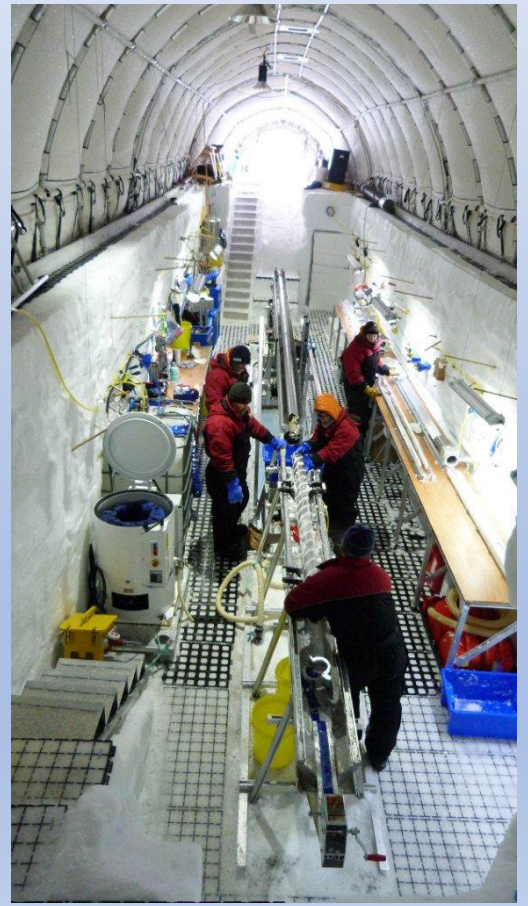
How to get climate data ? Proxydata Ice Cores

Proxydata (indirect data)

- Eisbohrkerne



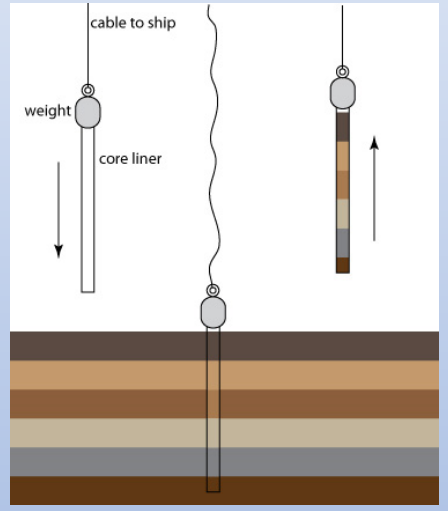
The ice core drill (in the middle) and a closer look at some of the components. The core barrel and chips chamber have been shortened in the drawing and the outer barrel (indicated by green) has been removed to reveal the parts inside

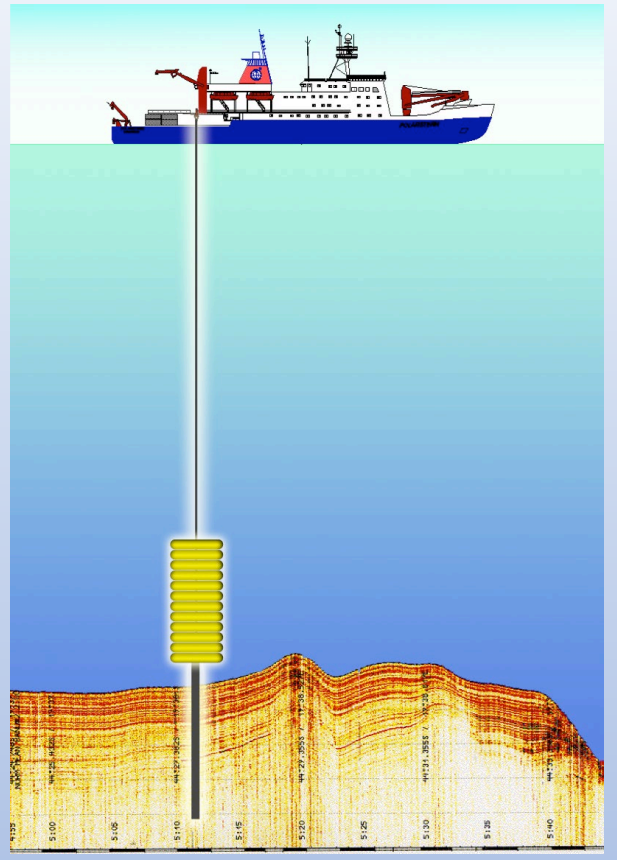


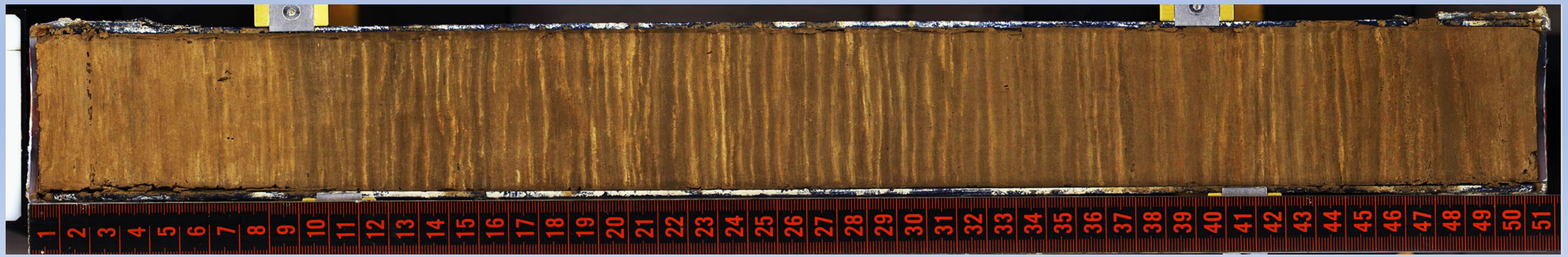
How to get climate data ? Proxydaten Sediment Cores

Proxydata (indirect data)

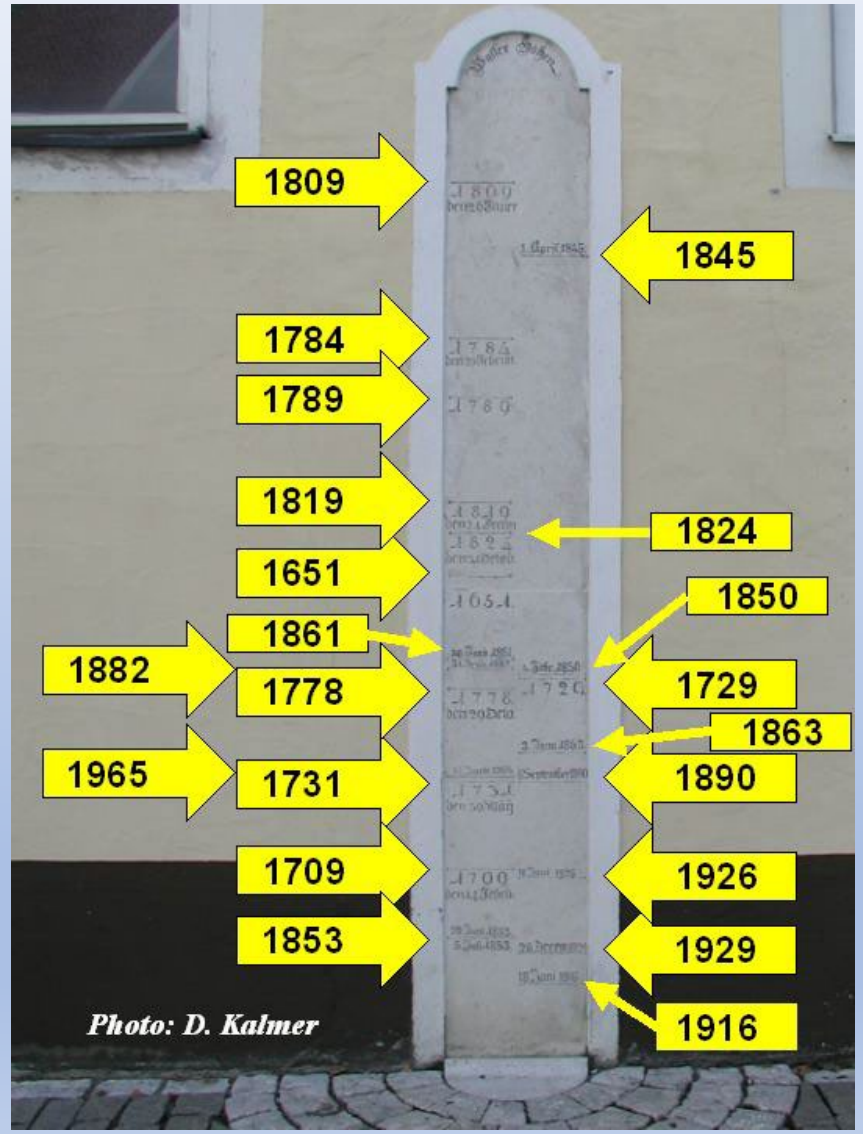
- Sedimentbohrkerne (Ozeanboden)



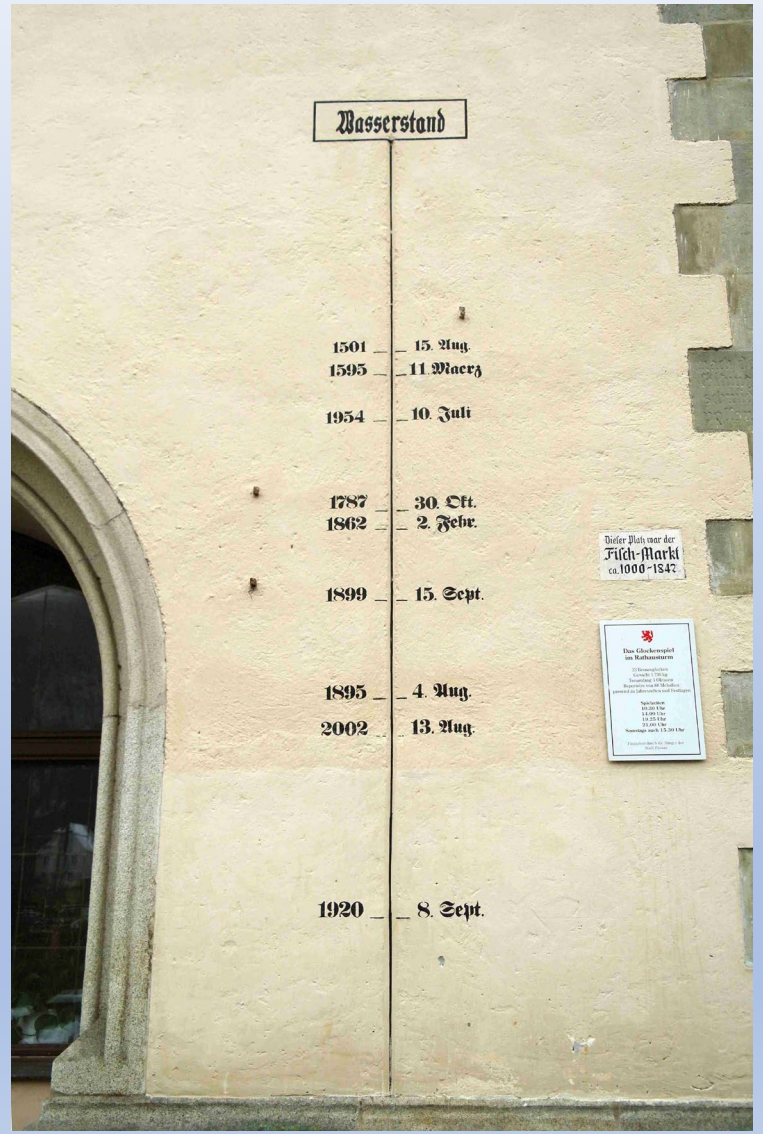




How to get climate data ? Proxydata Historical Gauges



Rhein Pegel Kelheim



Donau Pegel Passau

Nordsee Pegel Wyk

How to get climate data ? Proxydata Paitings

Little Ice Age 1565-1640 Hendrick Avercamp Ijsvermaak 1608

How to get climate data ? Proxydata Paintings

Little Ice Age 1565-1640 Pieter Breughel d.Ä. 1566 Census in Bethlehem

How to get climate data ? Proxydata Paintings

Little Ice Age 1565-1640 Pieter Breughel d.Ä. 1566 Hunters in Snow

Which are the physical factors for Climate ?

- All that determine weather

- Astronomy (Earhpath Parameters, Inclination of Earth Axis, Milankovich-Cycle)

- Geology (Volcanoes, Topographa, Glaciers)

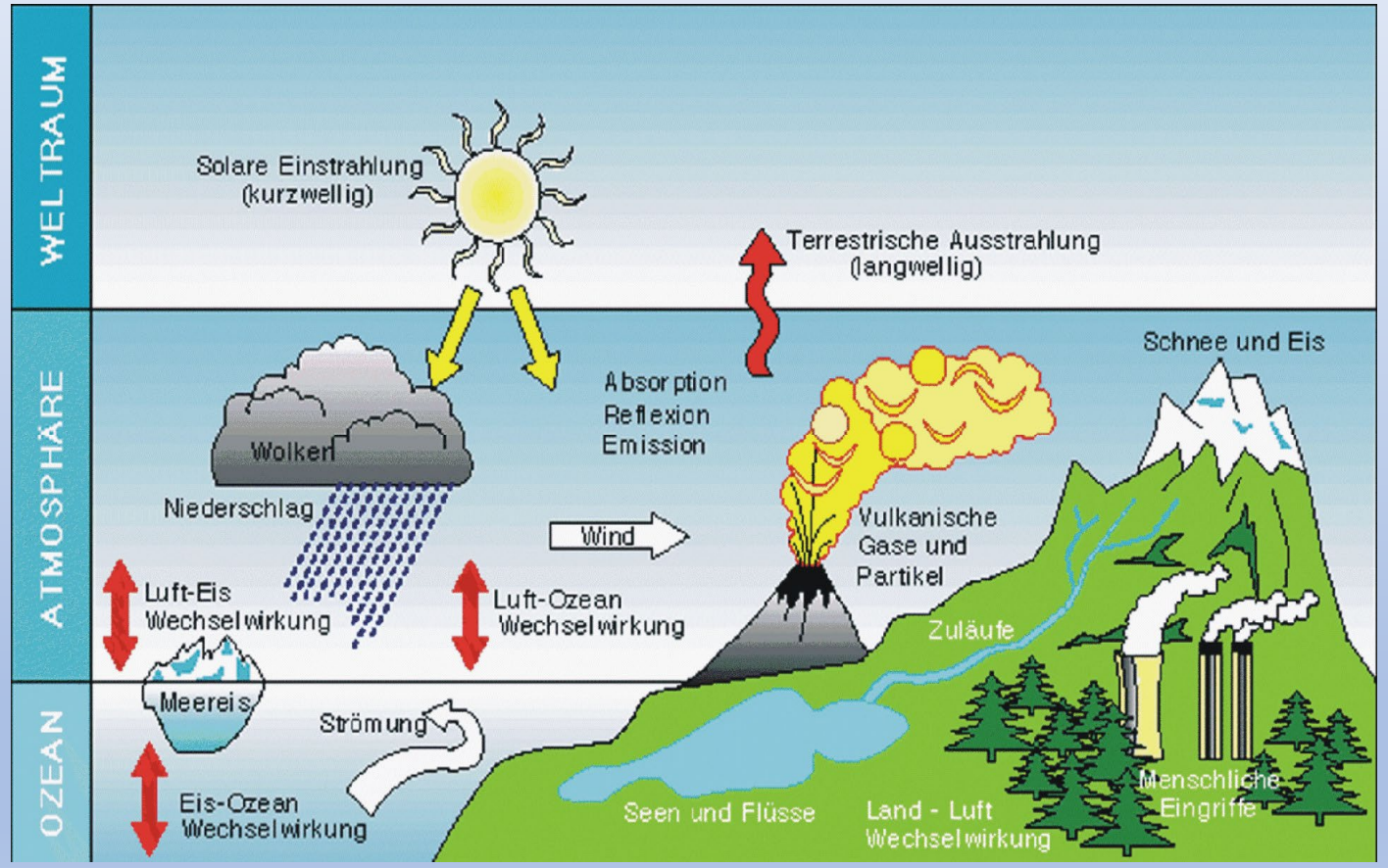
- Intensity of Solar radiation (Cycle of solar spots, Periode 11 years)

- Ocean-Atmosphere Interaction,
- Land-/Sea-Influence, Sea Ice Cover

- Local Phenomena Phänomene (El Niño)

- CO2-Sources: Anthropogenic
- (Burning of fossil fuel, Traffic, Industry,)

- CO2-Sinks: Vegetation, Tropical Rain Forest



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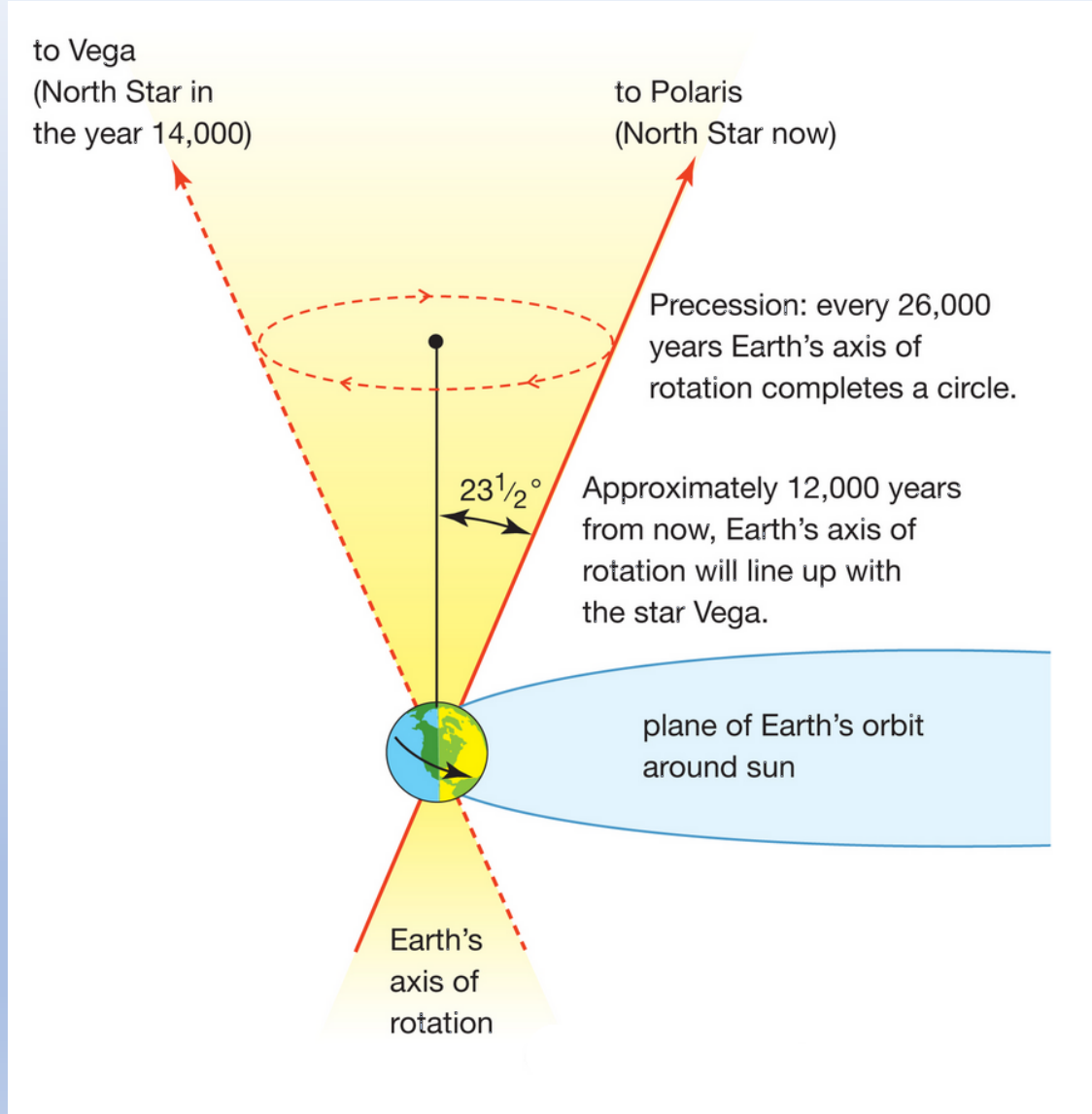

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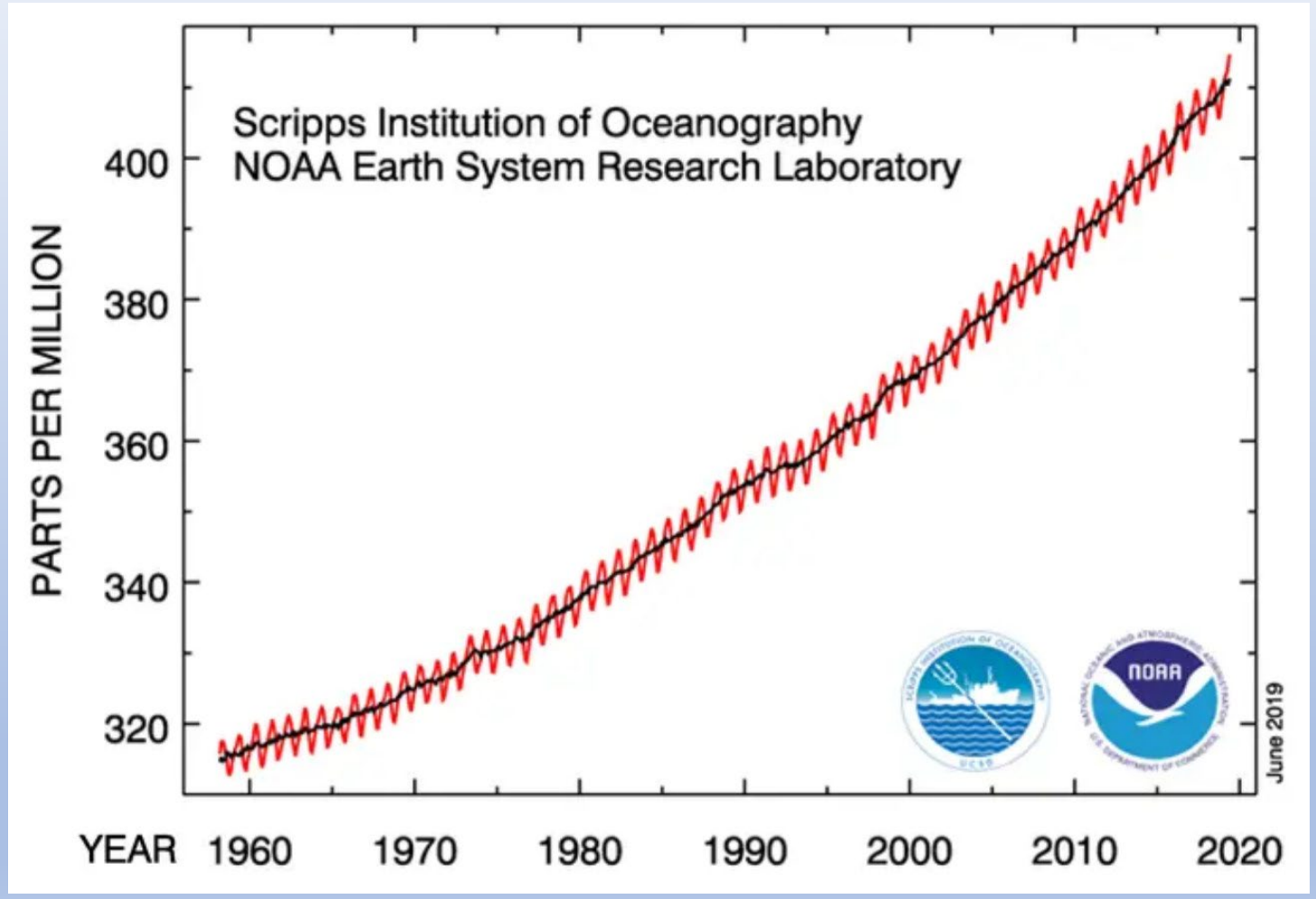

Which roll does CO_2 play in Climate and Global Change?

CO_2 absorbs longwave (Infrared) radiation thus warming the atmosphere

Were there no CO_2 in the Atmosphere,
the Global Temperature were about -15°C instead of 15°C

This is the Greenhouse Effect, which allows Life on Earth

Influence of CO_2 doubling: Svante Arrhenius Sweden 1896

Effect of CO2 in the Atmosphere Svante Arrhenius 1896 SWE

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

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Effect of CO2 in the Atmosphere Arrhenius 1896 ‚Climate Sensitivity‘

TABLE VII.—*Variation of Temperature caused by a given Variation of Carbonic Acid.*

Latitude.	Carbonic Acid=0·67.					Carbonic Acid=1·5.					Carbonic Acid=2·0.					Carbonic Acid=2·5.					Carbonic Acid=3·0.				
	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.	Dec.–Feb.	March–May.	June–Aug.	Sept.–Nov.	Mean of the year.
70	−2·9	−3·0	−3·4	−3·1	−3·1	3·3	3·4	3·8	3·6	3·52	6·0	6·1	6·0	6·1	6·05	7·9	8·0	7·9	8·0	7·95	9·1	9·3	9·4	9·4	9·3
60	−3·0	−3·2	−3·4	−3·3	−3·22	3·4	3·7	3·6	3·8	3·62	6·1	6·1	5·8	6·1	6·02	8·0	8·0	7·6	7·9	7·87	9·3	9·5	8·9	9·5	9·3
50	−3·2	−3·3	−3·3	−3·4	−3·3	3·7	3·8	3·4	3·7	3·65	6·1	6·1	5·5	6·0	5·92	8·0	7·9	7·0	7·9	7·7	9·5	9·4	8·6	9·2	9·17
40	−3·4	−3·4	−3·2	−3·3	−3·32	3·7	3·6	3·3	3·5	3·52	6·0	5·8	5·4	5·6	5·7	7·9	7·6	6·9	7·3	7·42	9·3	9·0	8·2	8·8	8·82
30	−3·3	−3·2	−3·1	−3·1	−3·17	3·5	3·3	3·2	3·5	3·47	5·6	5·4	5·0	5·2	5·3	7·2	7·0	6·6	6·7	6·87	8·7	8·3	7·5	7·9	8·1
20	−3·1	−3·1	−3·0	−3·1	−3·07	3·5	3·2	3·1	3·2	3·25	5·2	5·0	4·9	5·0	5·02	6·7	6·6	6·3	6·6	6·52	7·9	7·5	7·2	7·5	7·52
10	−3·1	−3·0	−3·0	−3·0	−3·02	3·2	3·2	3·1	3·1	3·15	5·0	5·0	4·9	4·9	4·95	6·6	6·4	6·3	6·4	6·42	7·4	7·3	7·2	7·3	7·3
0	−3·0	−3·0	−3·1	−3·0	−3·02	3·1	3·1	3·2	3·2	3·15	4·9	4·9	5·0	5·0	4·95	6·4	6·4	6·6	6·6	6·5	7·3	7·3	7·4	7·4	7·35
−10	−3·1	−3·1	−3·2	−3·1	−3·12	3·2	3·2	3·2	3·2	3·2	5·0	5·0	5·2	5·1	5·07	6·6	6·6	6·7	6·7	6·65	7·4	7·5	8·0	7·6	7·62
−20	−3·1	−3·2	−3·3	−3·2	−3·2	3·2	3·2	3·4	3·3	3·27	5·2	5·3	5·5	5·4	5·35	6·7	6·8	7·0	7·0	6·87	7·9	8·1	8·6	8·3	8·22
−30	−3·3	−3·3	−3·4	−3·4	−3·35	3·4	3·5	3·7	3·5	3·52	5·5	5·6	5·8	5·6	5·62	7·0	7·2	7·7	7·4	7·32	8·6	8·7	9·1	8·8	8·8
−40	−3·4	−3·4	−3·3	−3·4	−3·37	3·6	3·7	3·8	3·7	3·7	5·8	6·0	6·0	6·0	5·95	7·7	7·9	7·9	7·9	7·85	9·1	9·2	9·4	9·3	9·25
−50	−3·2	−3·3	—	—	—	3·8	3·7	—	—	—	6·0	6·1	—	—	—	7·9	8·0	—	—	—	9·4	9·5	—	—	—
−60																									

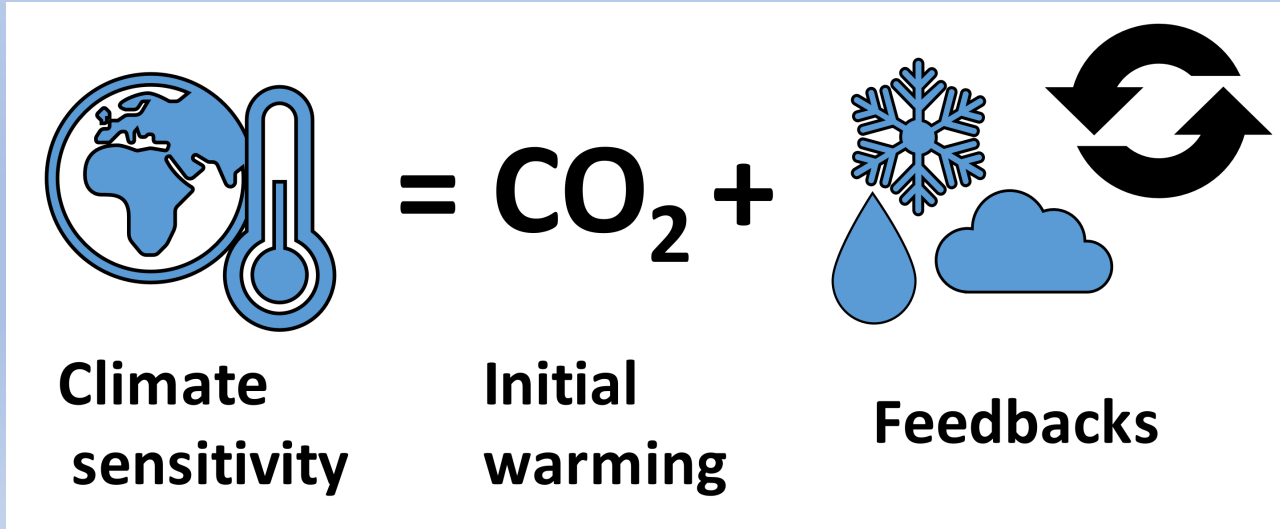
Effect of CO2 in the Atmosphere ‚Climate Sensitivity‘

‚Climate Sensitivity‘ describes Increase of Global Mean Temperature for CO2 Doubling

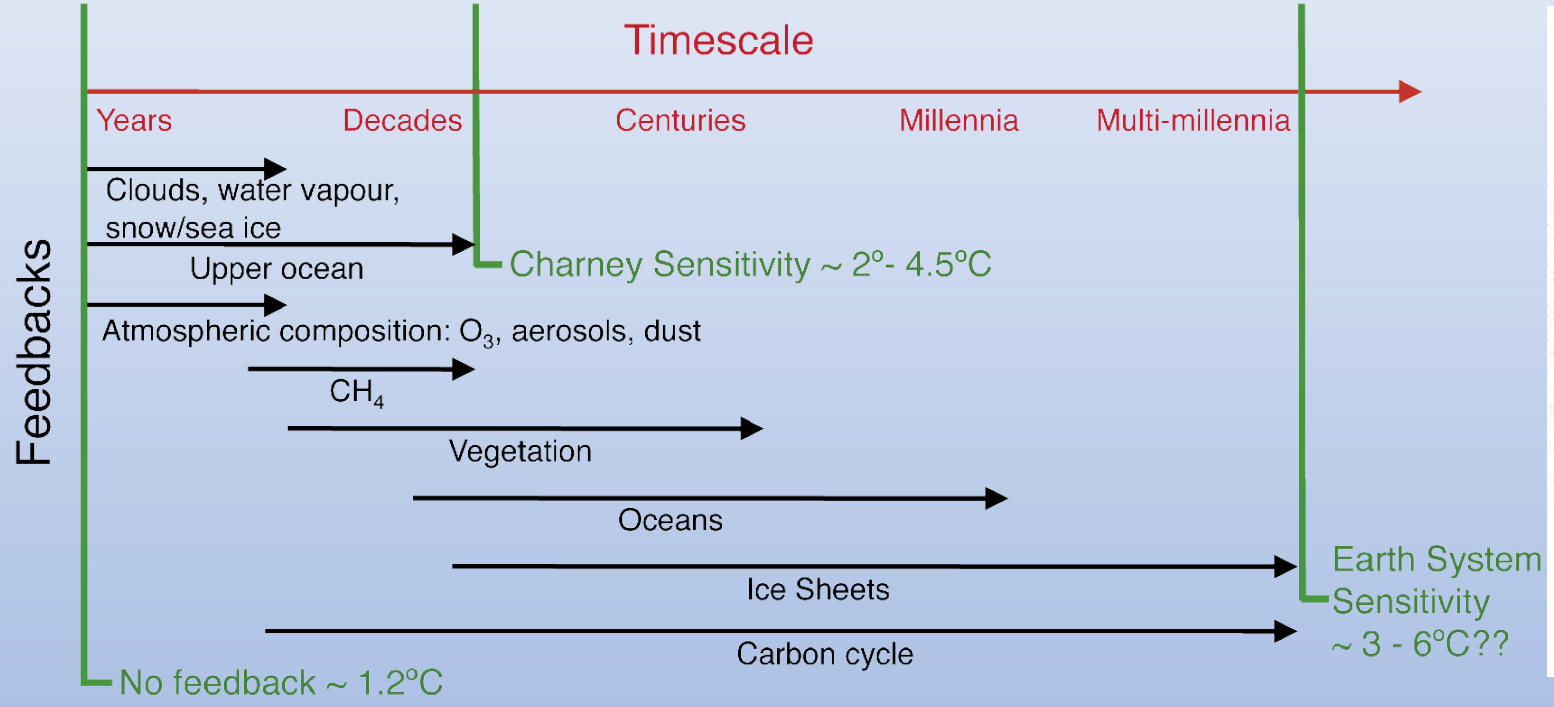
It is the most important issue in the Climate Change Discussion and varies

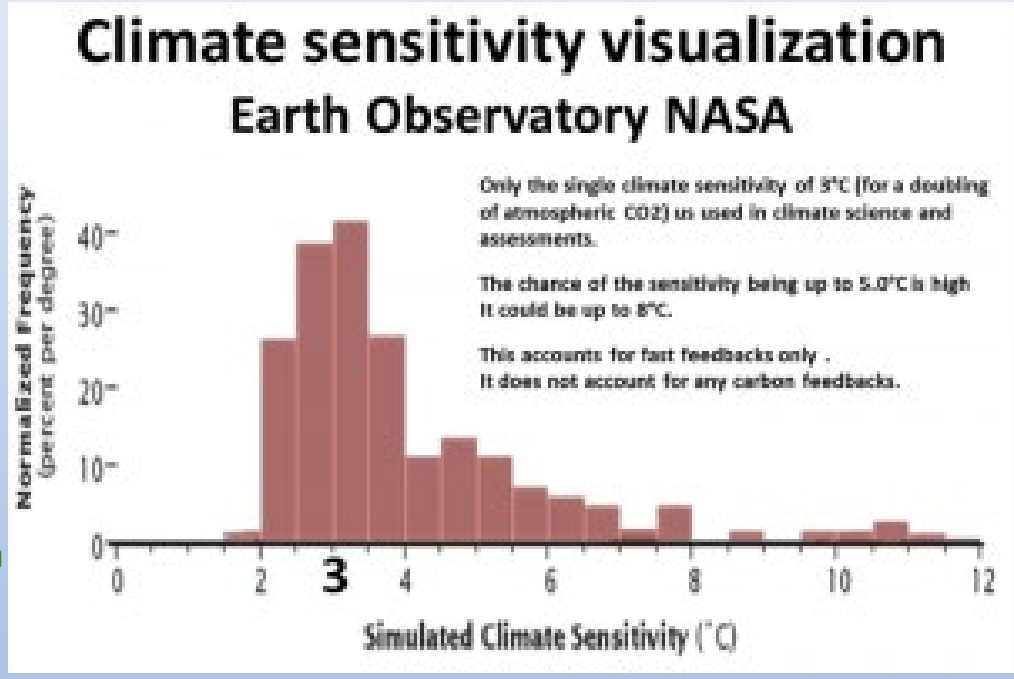
between ~2 K Global Warming Deniers

and 4-5 K IPCC, confirmed by latest observations

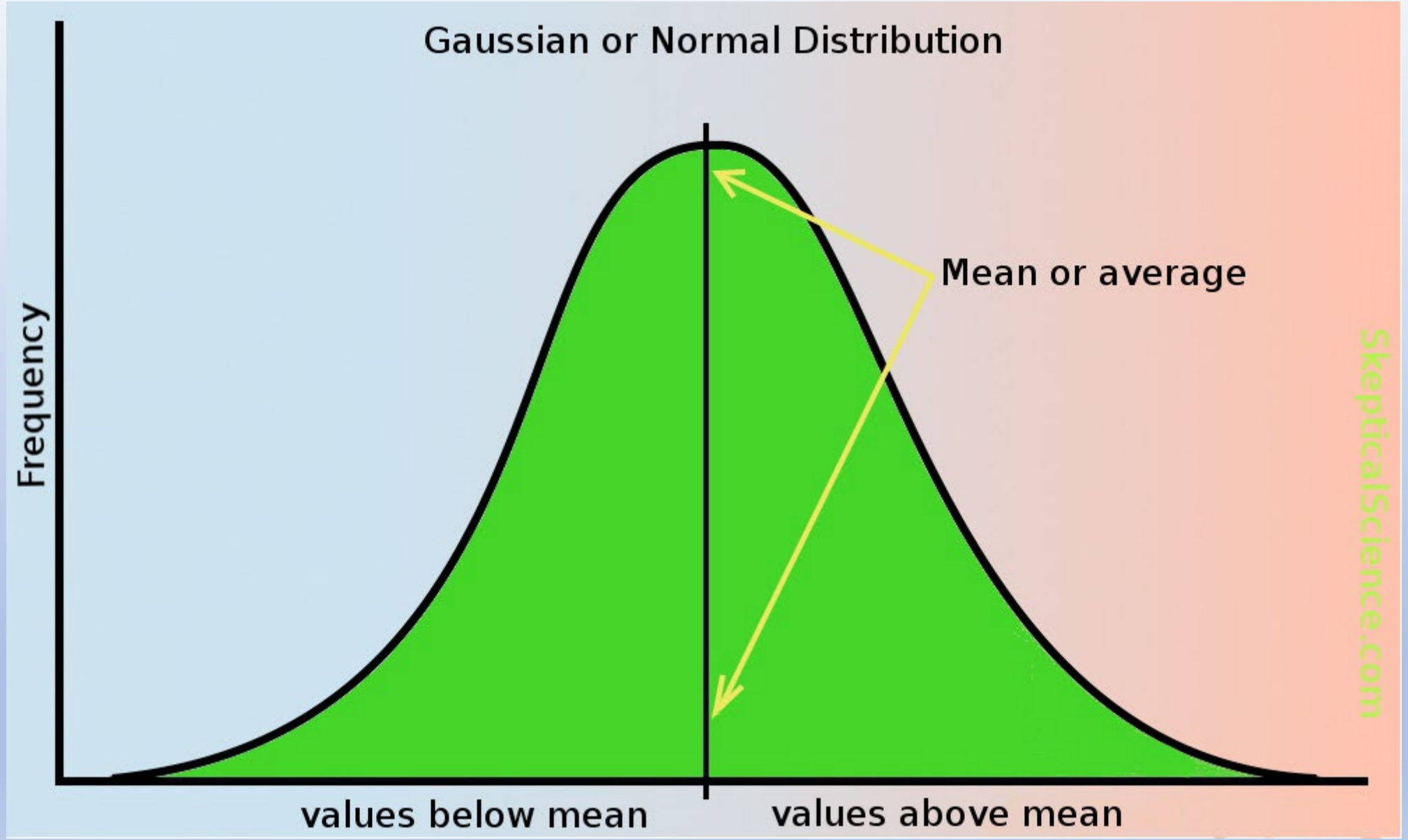


Climate Feedbacks and Sensitivity to $2xCO_2$

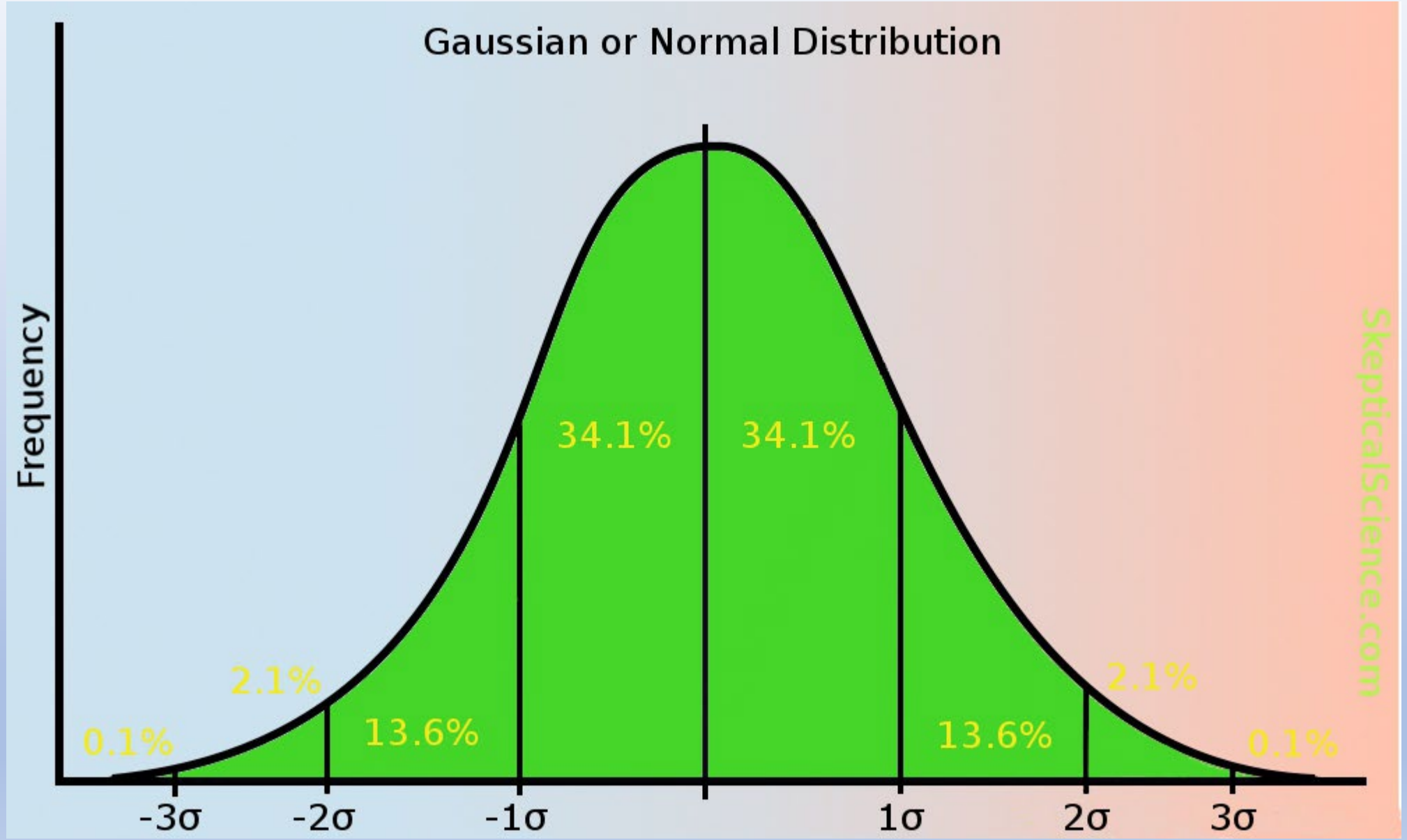




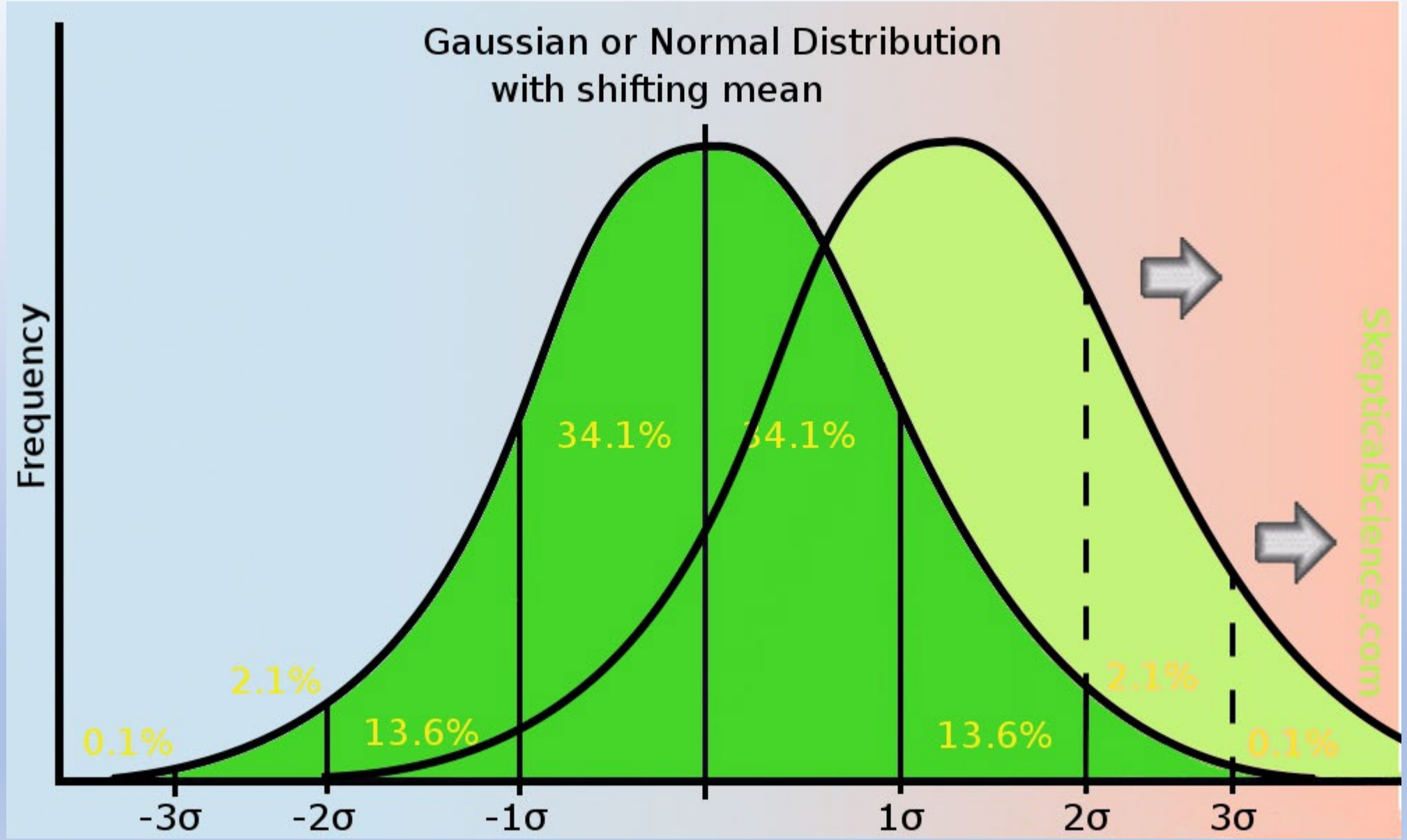
Distribution of Global Temperature and Global Warming



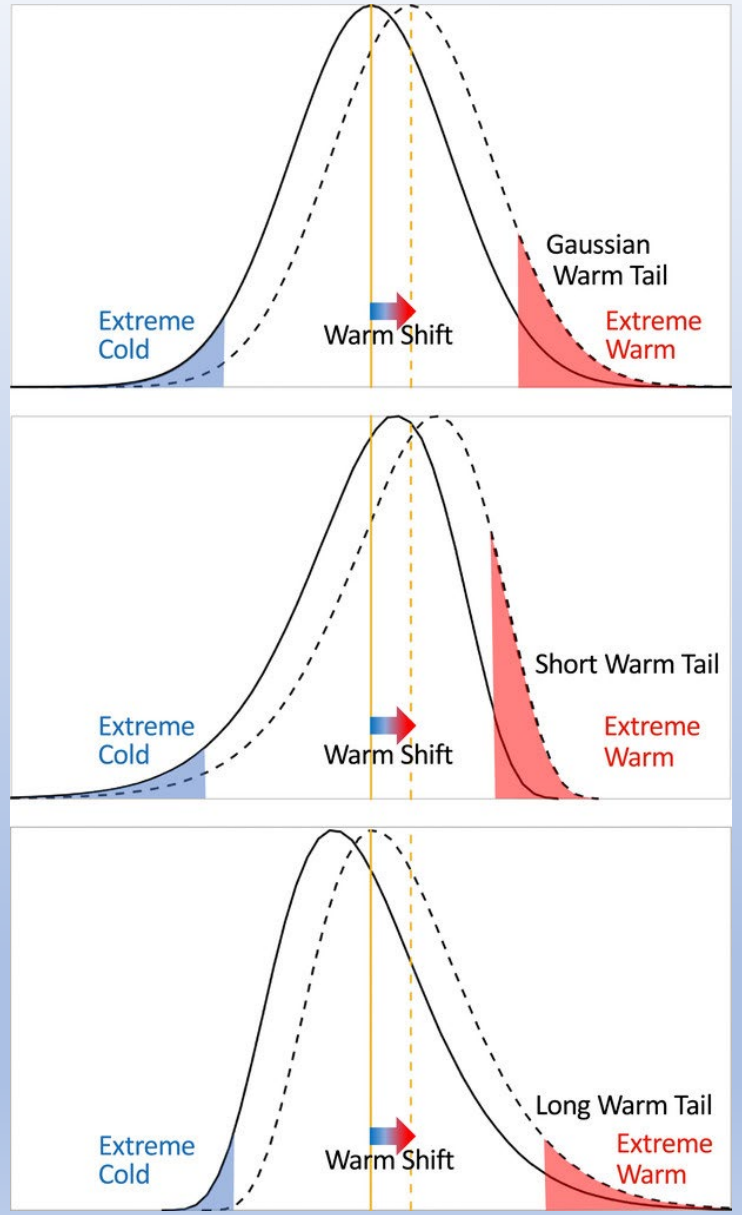
Distribution of Global Temperature and Global Warming



Distribution of Global Temperature and Global Warming



Distribution of Global Temperature and Global Warming



The effect of non-Gaussian warm and cold tails on changes in extreme temperature exceedances relative to a fixed threshold under a uniform warm shift.

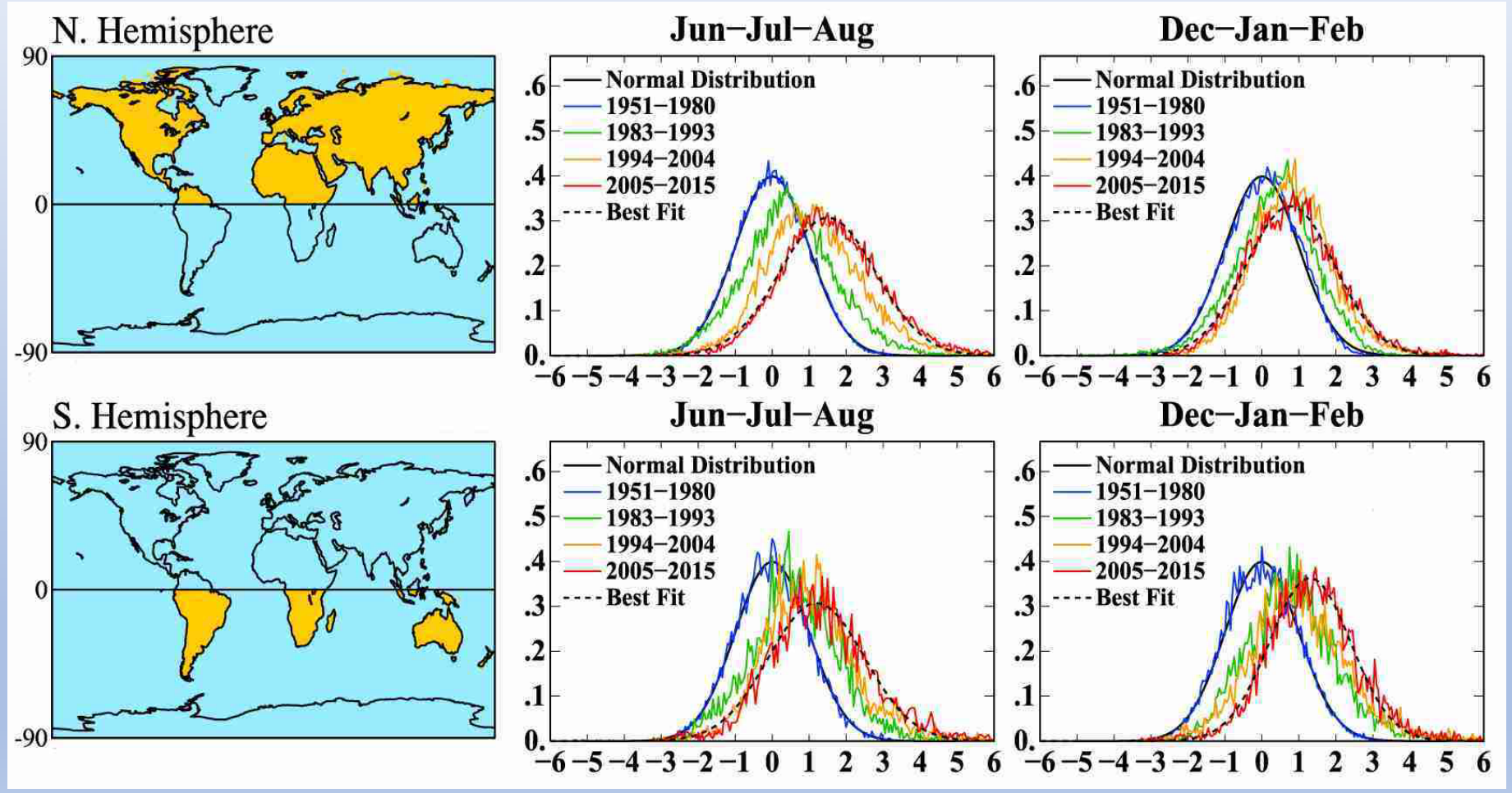
The red- and blue-shaded areas represent exceedances of fixed warm and cold temperature thresholds, respectively.

The solid curve is the preshifted probability distribution and the dashed curve is the same distribution after a uniform warm (rightward) shift. The yellow vertical lines are the preshifted (solid) and postshifted (dashed) distribution means.

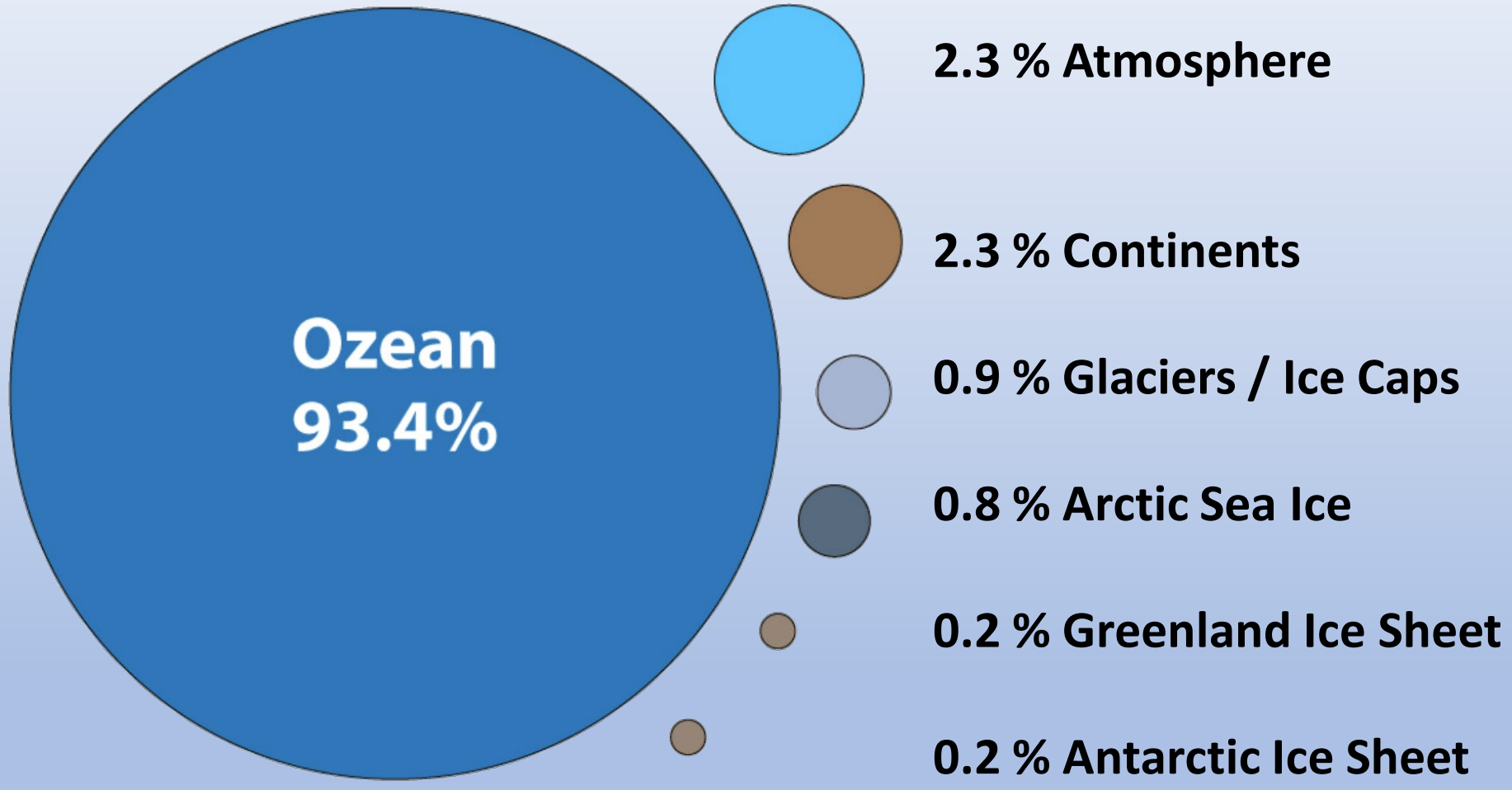
Examples are for (top) a Gaussian, (middle) a short warm-tailed distribution, and (bottom) a long warm-tailed distribution.

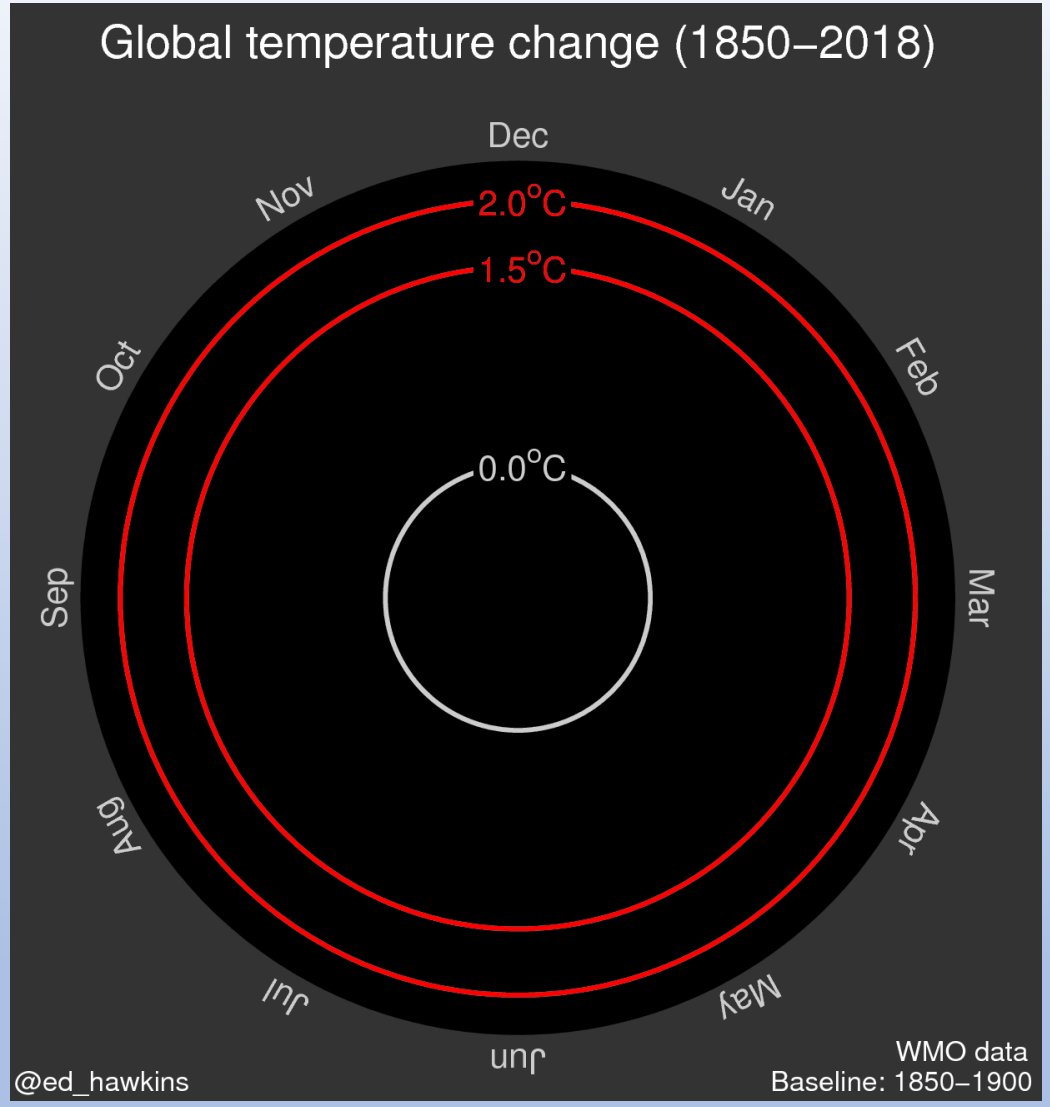
https://journals.ametsoc.org/view/journals/clim/31/23/jcli-d-17-0878.1.xml

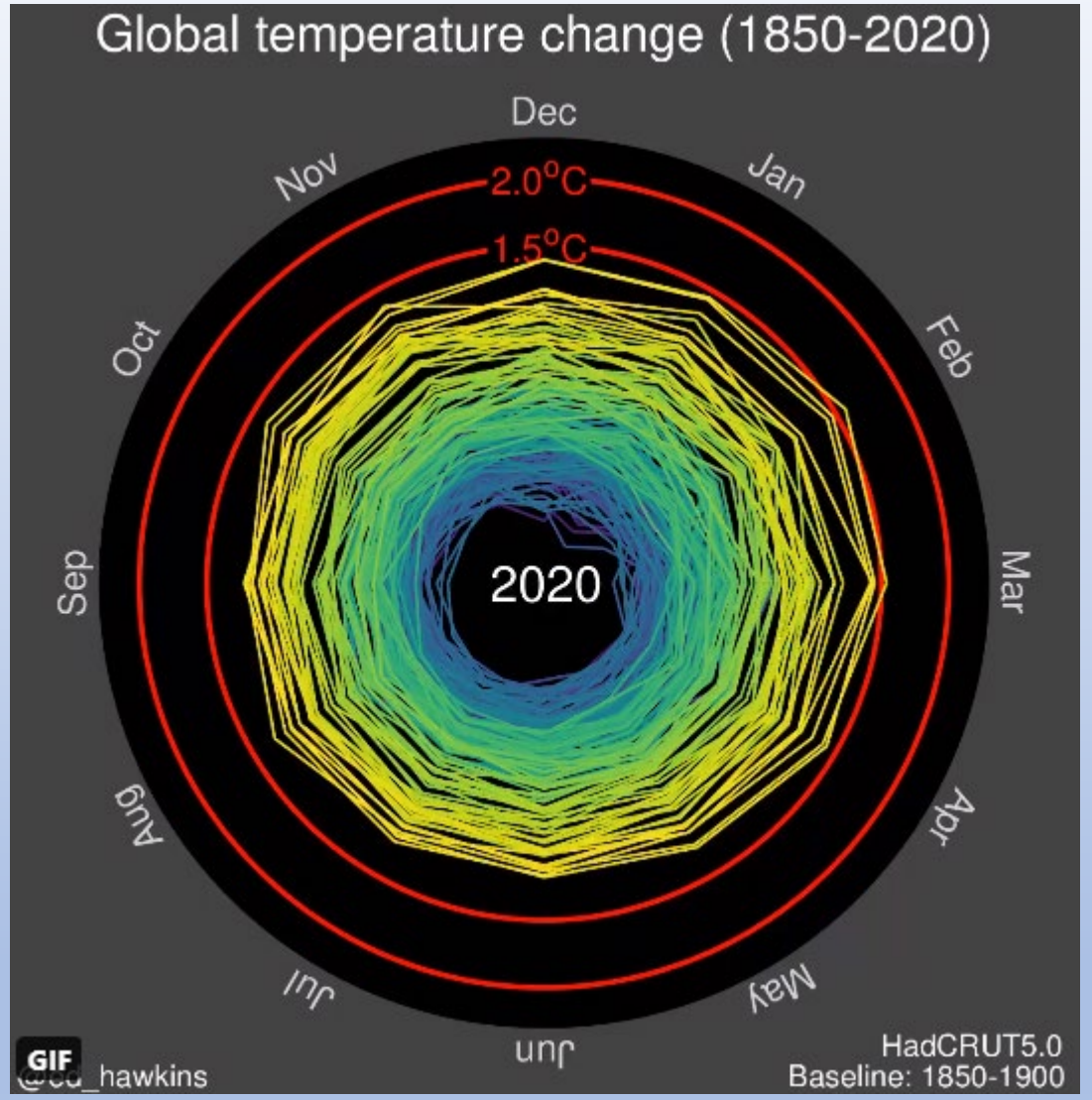
Statistical Consequences of Global Warming
Less / More Extremes of Cold / Heat

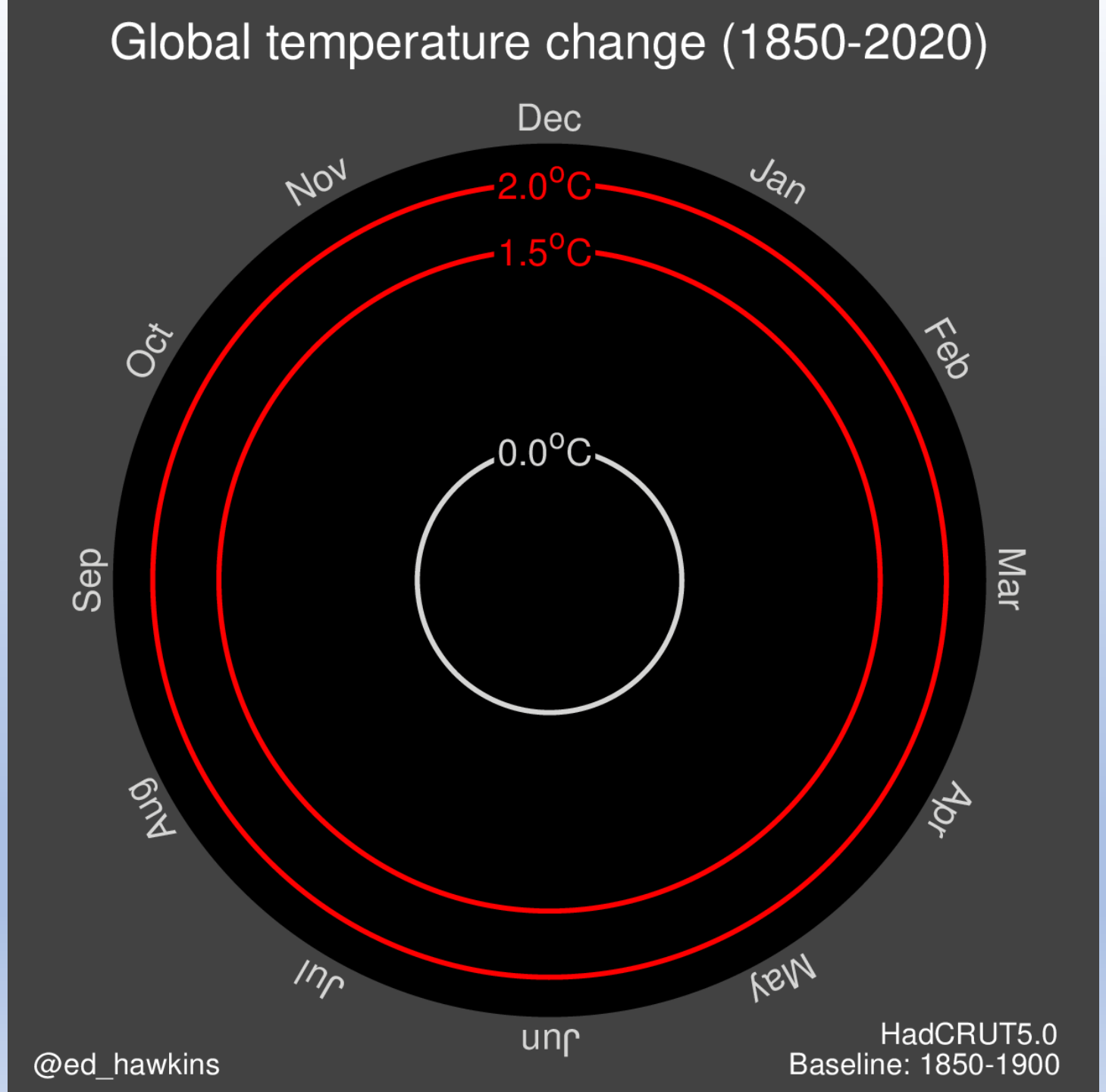


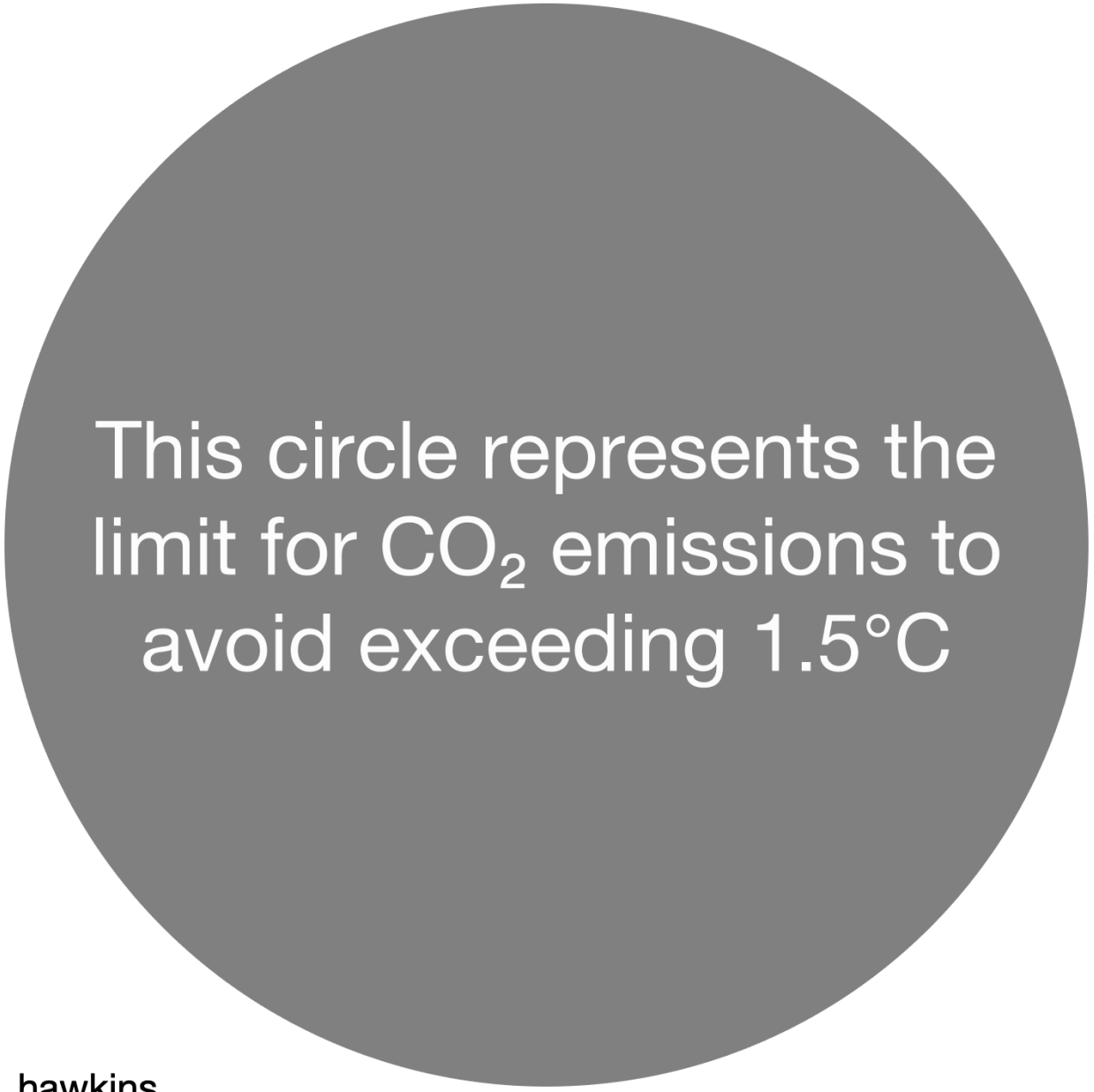
Where does the Global Warming end up ?



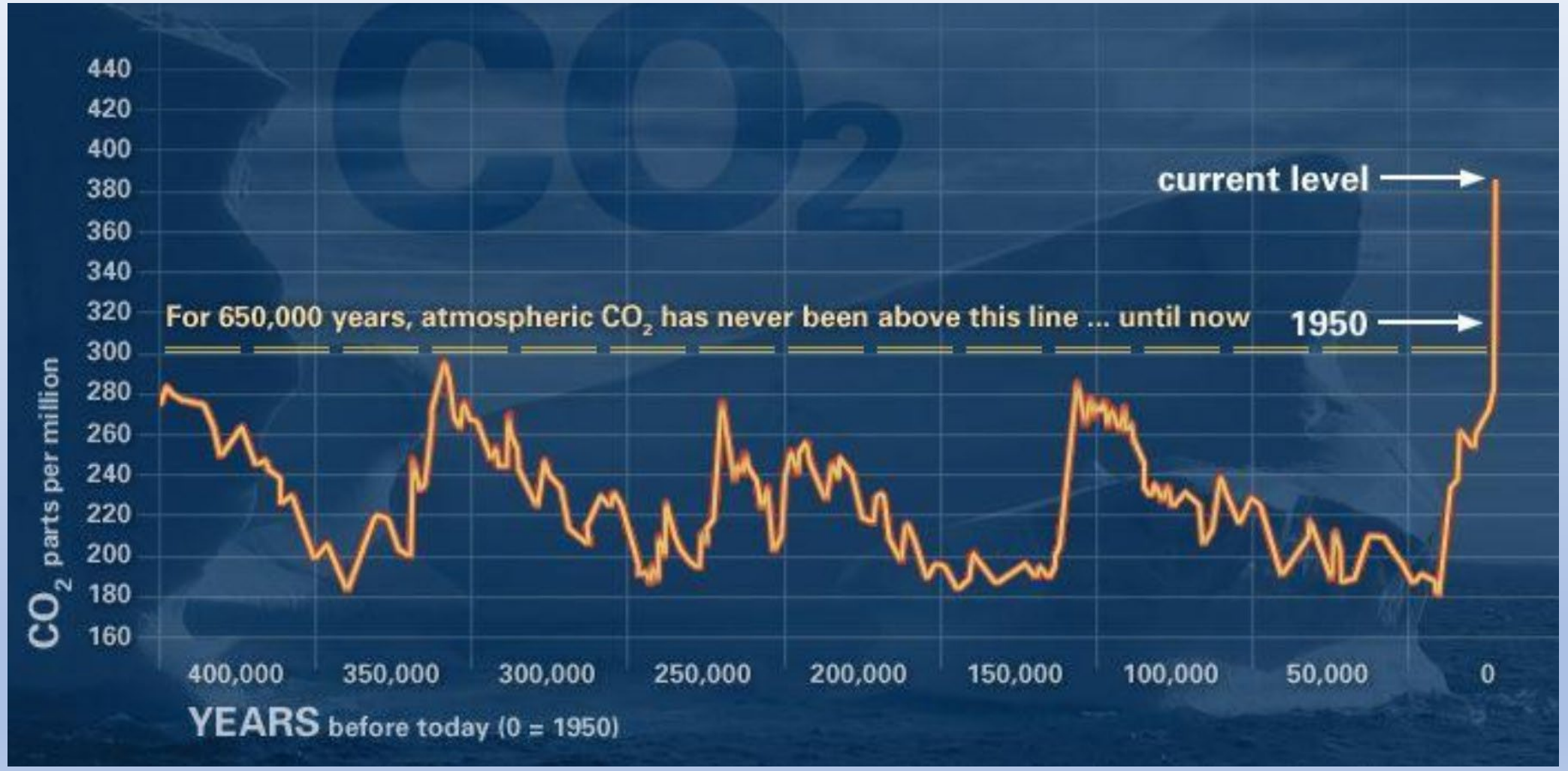

Global temperature change (1850–2018)
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2.0°C
1.5°C
0.0°C
@ed_hawkins
WMO data
Baseline: 1850–1900

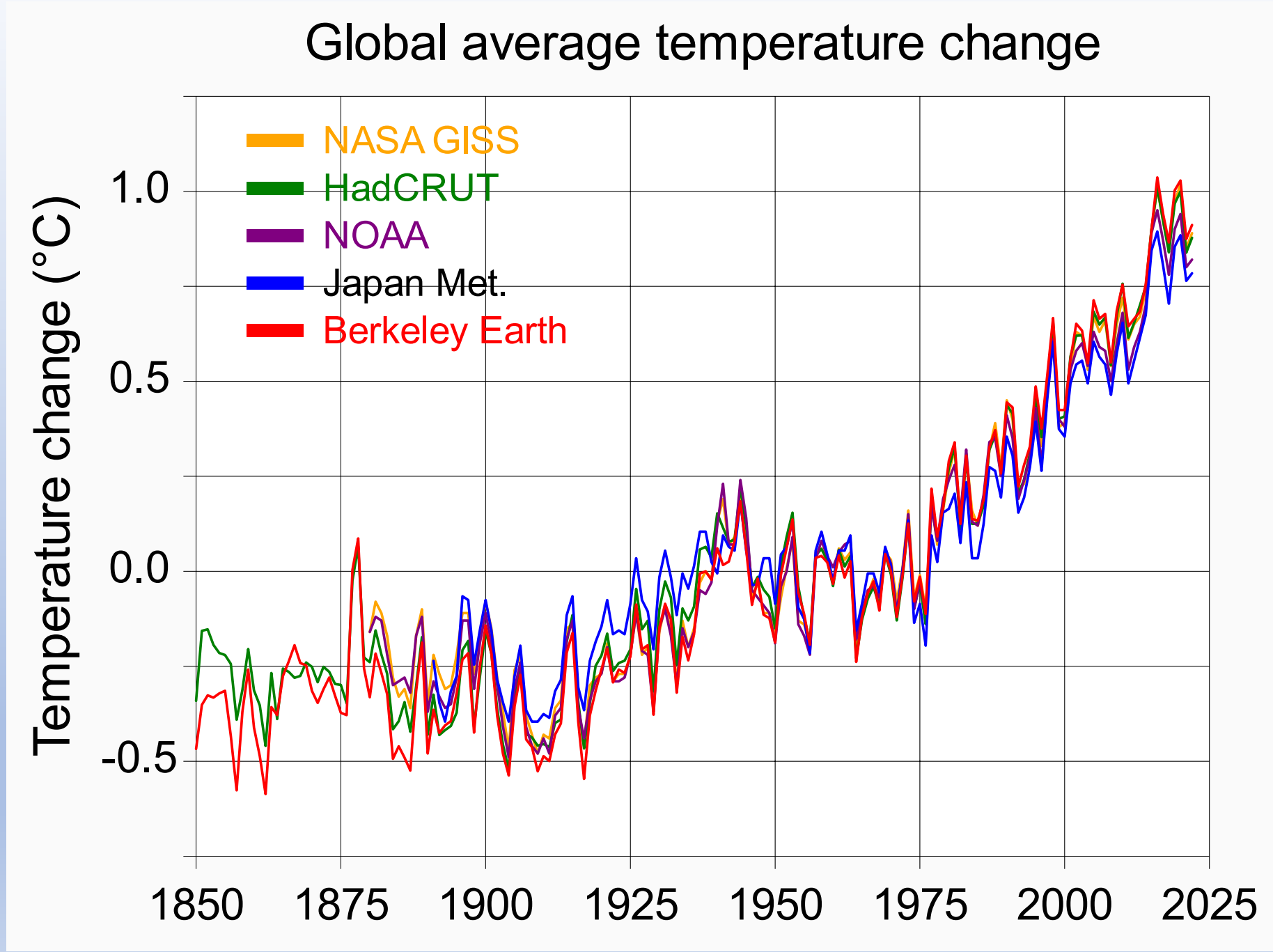

Global temperature change (1850-2020)
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2.0°C
1.5°C
2020
GIF
HadCRUT5.0
Baseline: 1850-1900


Global temperature change (1850-2020)
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
2.0°C
1.5°C
0.0°C
@ed_hawkins
HadCRUT5.0
Baseline: 1850-1900

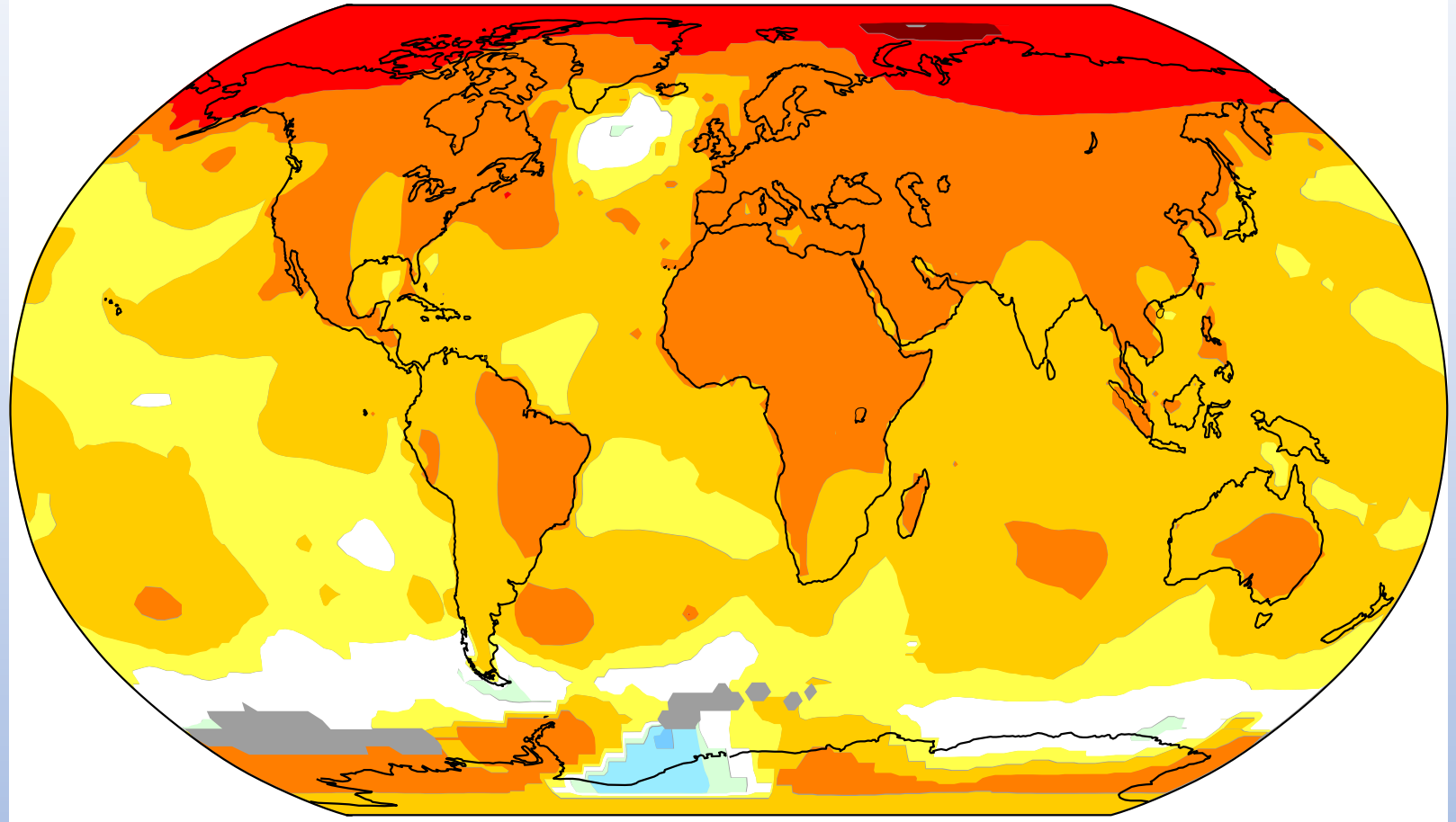

This circle represents the limit for CO_2 emissions to avoid exceeding 1.5°C

@ed_hawkins


440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
CO2 parts per million
current level
For 650,000 years, atmospheric CO2 has never been above this line ... until now
1950
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
YEARS before today (0 = 1950)


Global average temperature change
NASA GISS
HadCRUT
NOAA
Japan Met.
Berkeley Earth
Temperature change (°C)
1.0
0.5
0.0
-0.5
1850
1875
1900
1925
1950
1975
2000
2025

Temperature change in the last 50 years



2011–2021 average vs 1956–1976 baseline

−1.0 −0.5 −0.2 +0.2 +0.5 +1.0 +2.0 +4.0 °C

−1.8 −0.9 −0.4 +0.4 +0.9 +1.8 +3.6 +7.2 °F

Questions you should be able to answer: Climatology

What is the effect of CO2 in the atmosphere? How can it be described?

- CO2 absorbs the outgoing longwave IR radiation thus warming the atmosphere. The effect can be described by the Climate sensitivity which describes the temperature increase in case of doubling CO2. The current CO2 level in the aztmosphere is approx. 420 ppm. The estimates of the climate sensitivity varies between 2K and 5 K. It has first been estimated in 1896 by the Swedish chemist Svante Arrhenius in exactly this range.

What is the effect of increase of global temperature in terms of weather?

- The air temperature distribution can be described by the Gaussian distribution. An increase of the mean value has the following effects:
    1. Higher warm extreme values, which have not been observed before, will occur
    2. The frequency of warm extreme values observed in the past will increase (more cases)
    3. The frequency of cold extreme values observed in the past will decrease (less cases)

Where does the Global Warming end up?

- More than 90 % in the Ocean, 2 % in the atmosphere