Workshop on Quality Assurance Framework for Earth Observation (QA4EO)
29 September – 1 October, 2009, Antalya

The Importance of Traceability for Climatology

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Outline

- The climate system
- Climatological Observations

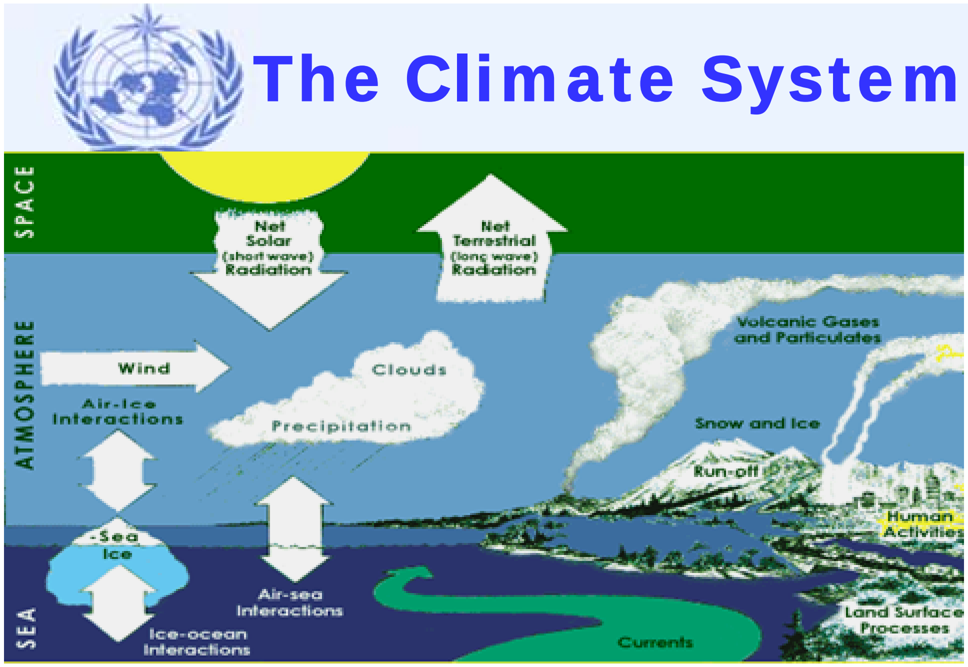
  In-situ (Proxy, Historical, Conventional, AWOS, etc)

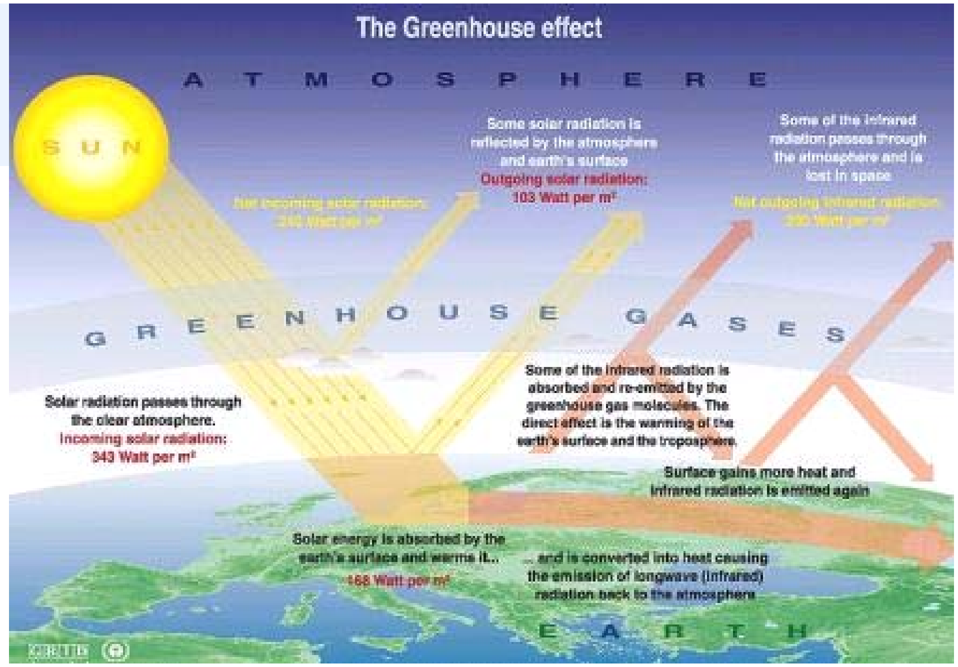
  Remote sensing (Radar, Lidar, Satellite, etc)
- Calibration and QC of observational data

  Laboratory check, limit check, internal consistency, relational and area control
- Metadata issue
- Climate data management

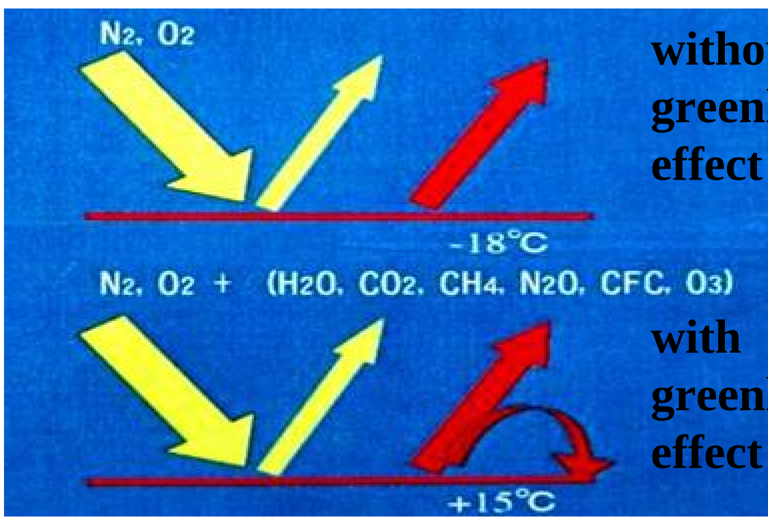
  Archive, access and retrieval, QC, homogeneity, statistical process, missing value estimation, data rescue, exchange
- Traceability of observation

  Time series, monitoring, indices, graphics, climate atlas
- Conclusion
- Acknowledgement





Climate system is comprised by the complicated interactions among the atmosphere, the ocean, the cryosphere, the surface lithosphere and the biosphere.



without greenhouse effect

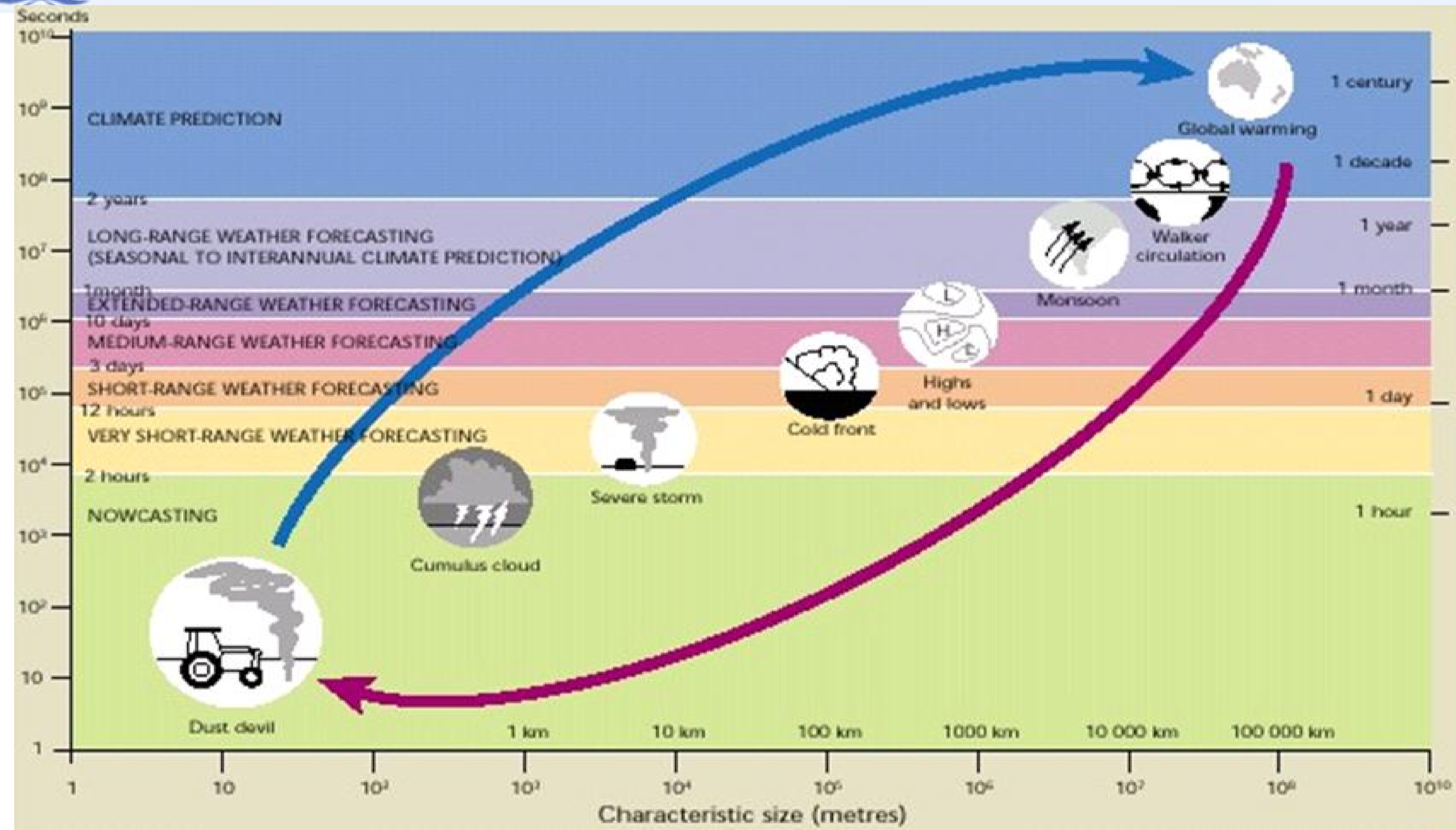
with greenhouse effect

Energy from the sun drives the earth's weather and climate, and heats the earth's surface; in turn, the earth radiates energy back into space. The greenhouse effect is a necessary phenomenon. Without it Earth temperature would be -18°C. But the Greenhouse gases trap some of the outgoing energy and maintain Earth's temperature 15°C. However, too many greenhouse gases could increase in mean temperatures

Radiative flux balance

$$\pi r^2 S_0(1-a) = 4\pi r^2 \sigma T^4 \qquad T=\sqrt[4]{\frac{(1-0.3)\times 1.37\times 10^3}{4\times 5.67\times 10^{-8}}} = 255\text{K} = -18^\circ\text{C}$$

Lifetime of atmospheric phenomena



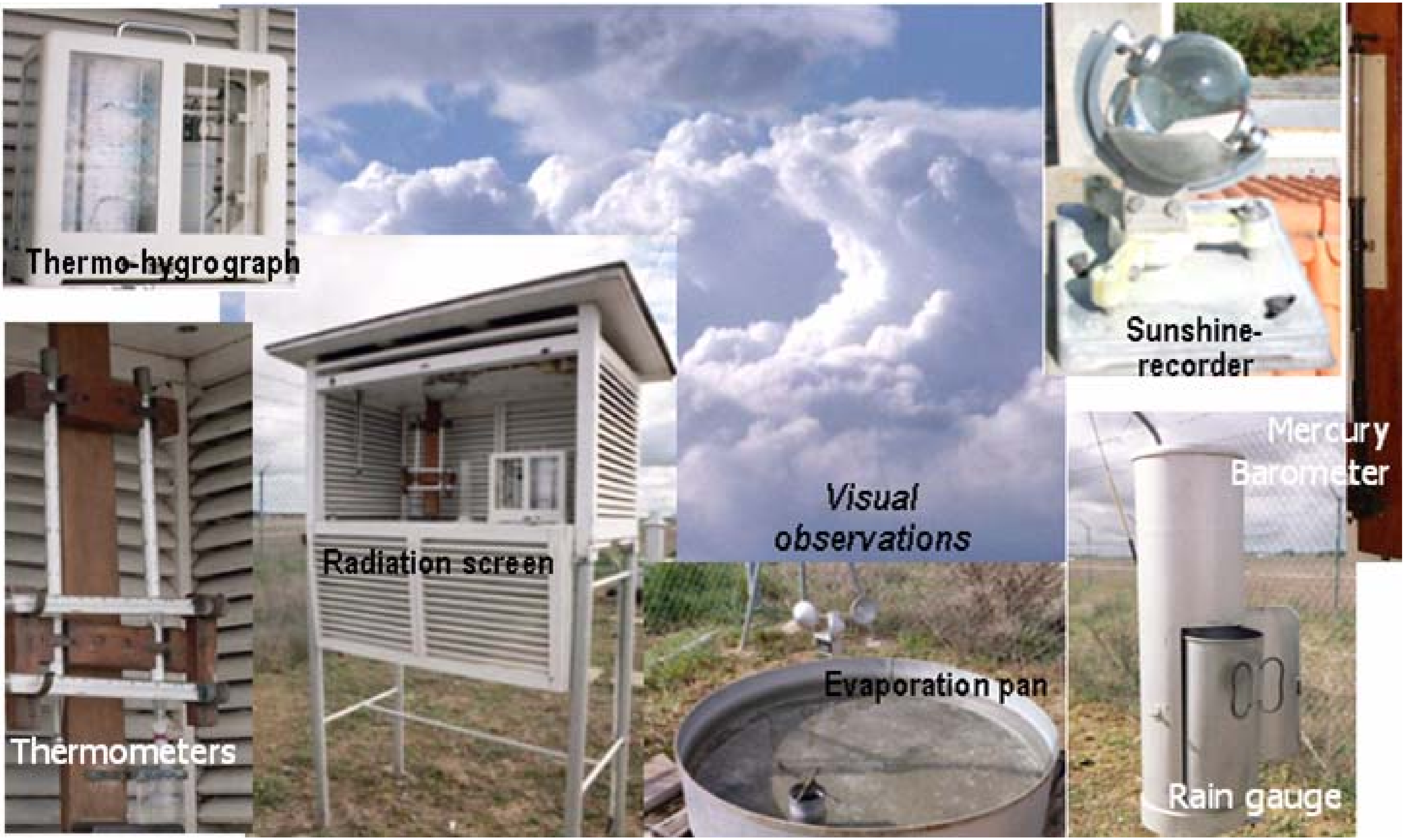
Climate is traditionally viewed as the integration of discreet weather events and variables over time and space

Scale name	Time scale	Horizantal scale	Vertical scale
Microscale	0.1 second to 1 minute	<1 mm to 100 m	<1 mm to 3 m
Toposcale (local scale)	3 seconds to 30 minutes	10 m to 3 km	1 m to 100 m
Mesoscale (regional scale)	1 minutes to 3 hours	300 m to 30 km	10 m to 1 km
Synoptic scale	1 hour to 1 day	3 km to 1000 km	100 m to 10 km
Macroscale	1/2 day to 1 week	30 km to 10000 km	1 km to 20 km
Global scale	3 days and longer	300 km to globe	1 km to 100 km

Table: Summary of atmospheric scales in time and space

(by J.W. Zillman, WMO Bulletin 48 No.2

Conventional Climatological Observations and Instruments



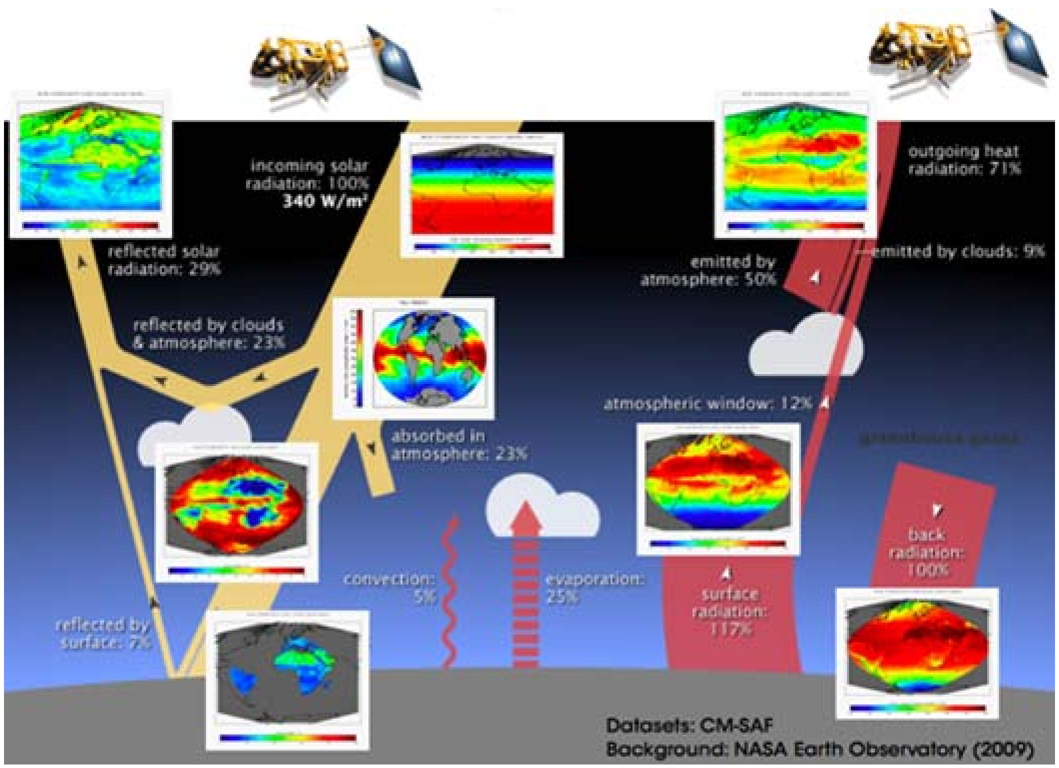
Automatic Weather Observation Station (AWOS) sensors and equipments

Instrument and sensor calibration

Opening the Meteorological Calibration Center (KALMER) in TSMS, *24.09.2009*

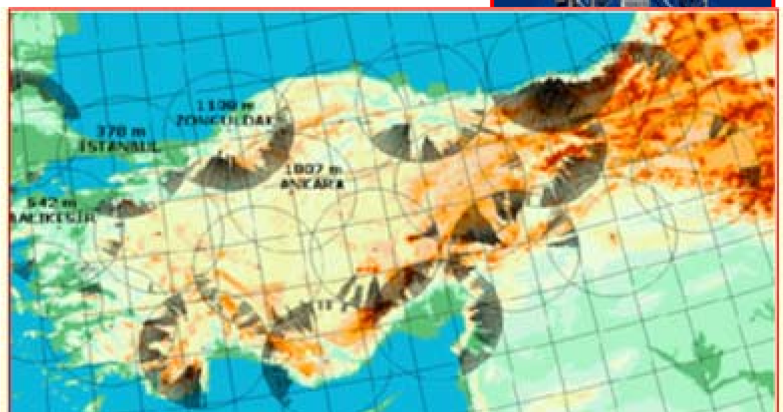
Remote sensing observations

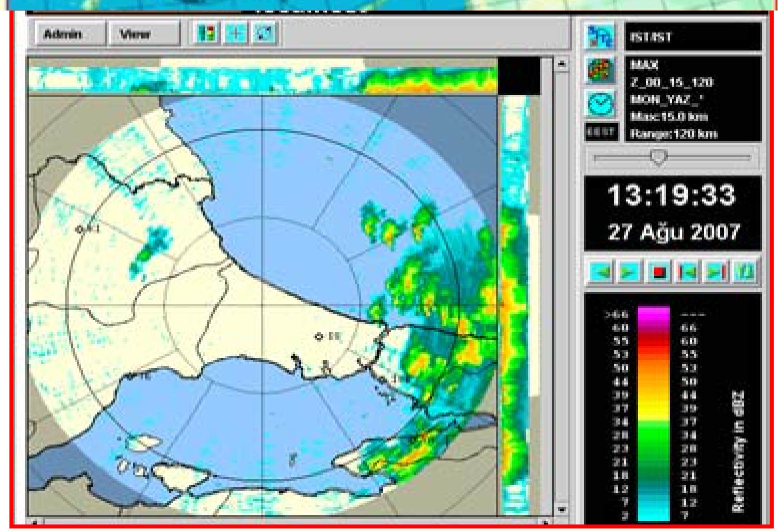
CM-SAF (Satellite Application Facility on Climate Monitoring)



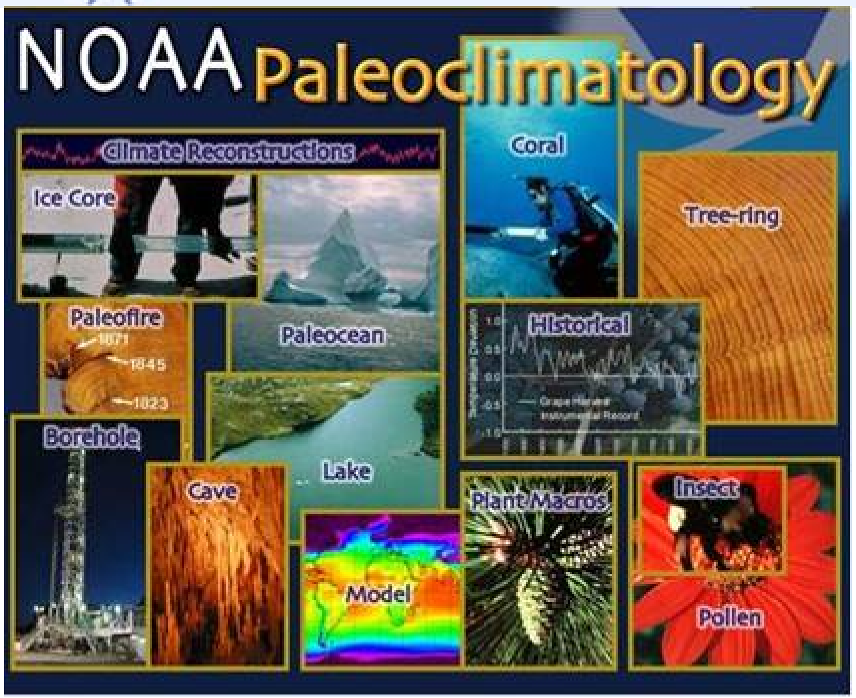
Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data and form an integral part of the distributed EUMETSAT Application Ground Segment.

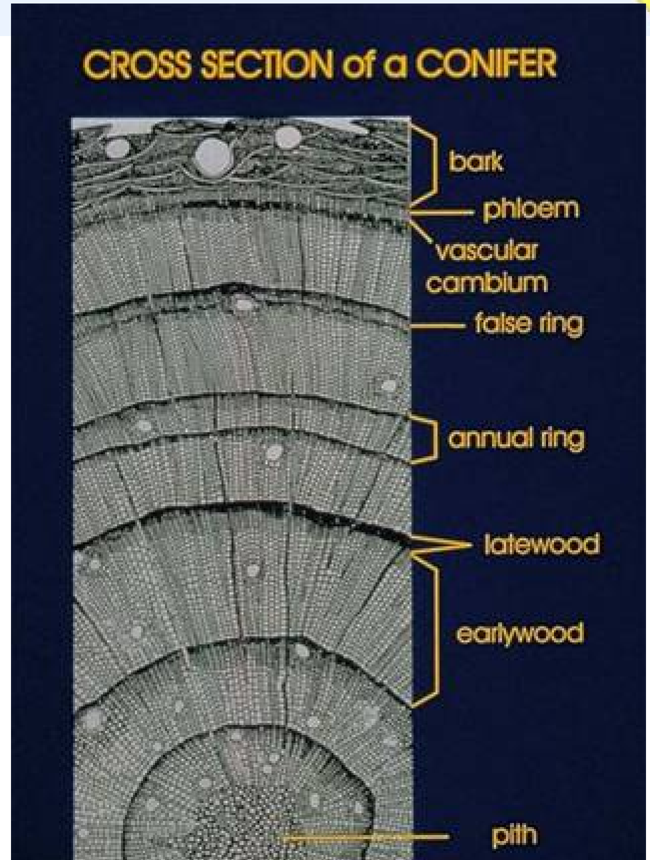
Radar observation





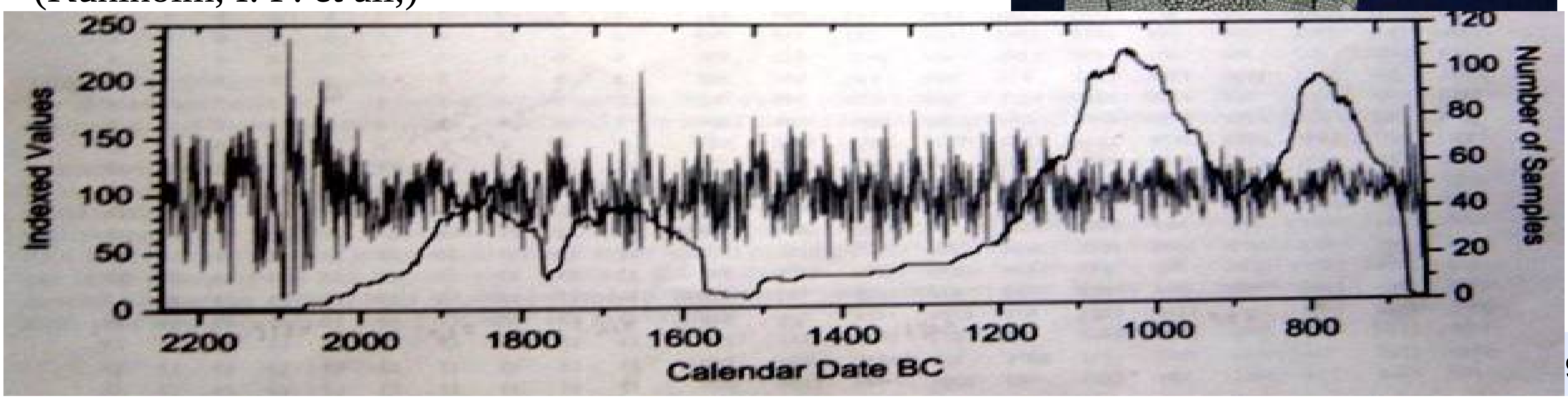
Paleoclimatology (The study of ancient climates)





Dendrochronological Dating in Anatolia:

(Kuniholm, I. P. et all,)



Historical data & Data Rescue

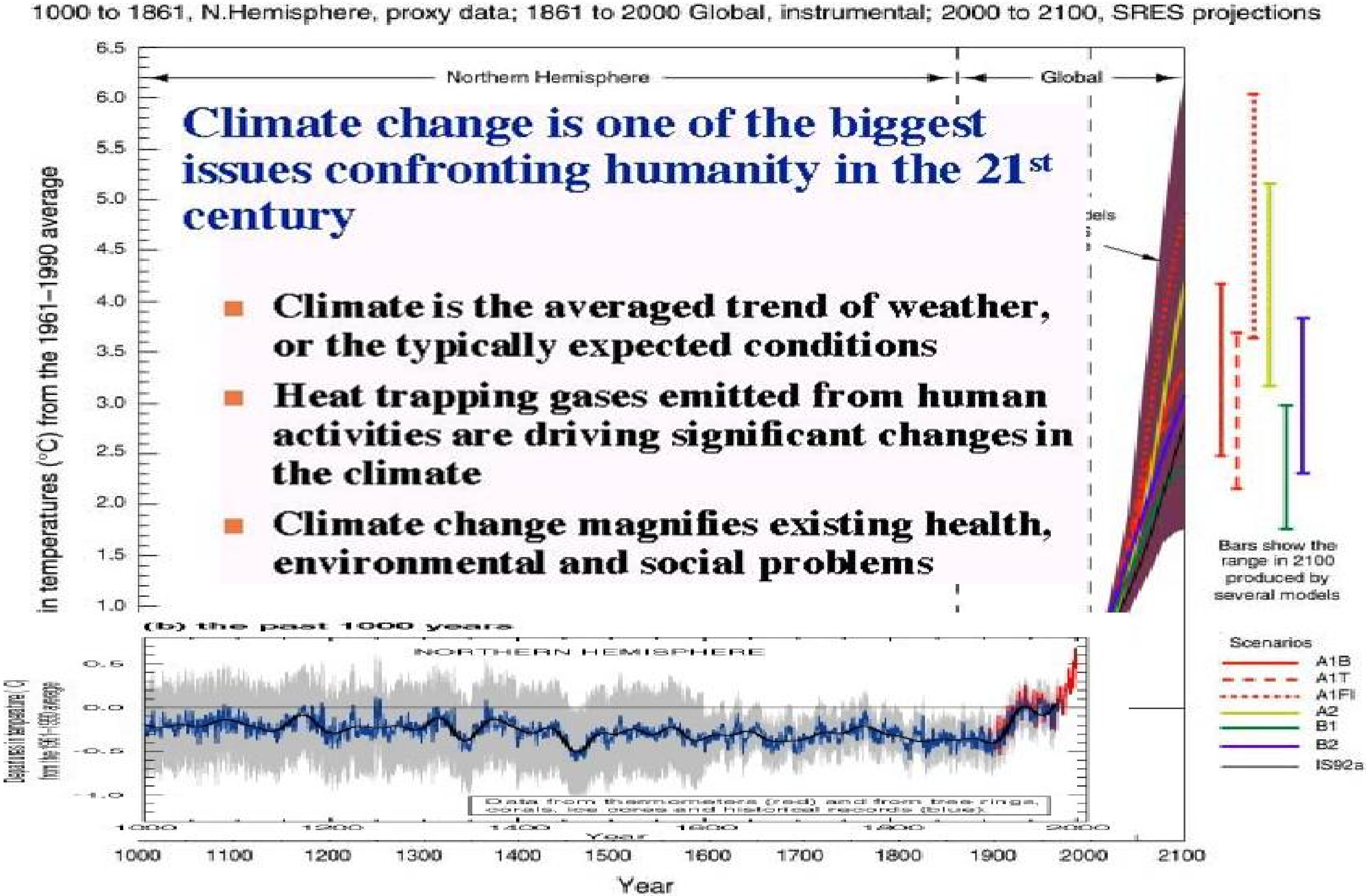
Climate data archive waiting for rescue

Data Rescue is :

an ongoing process of preserving all data at risk of being lost due to deterioration of the medium, and the digitization of current and past data into computer compatible form for easy access. There are several on going data rescue program.

WMO MEDARE Initiative *is one of them.*

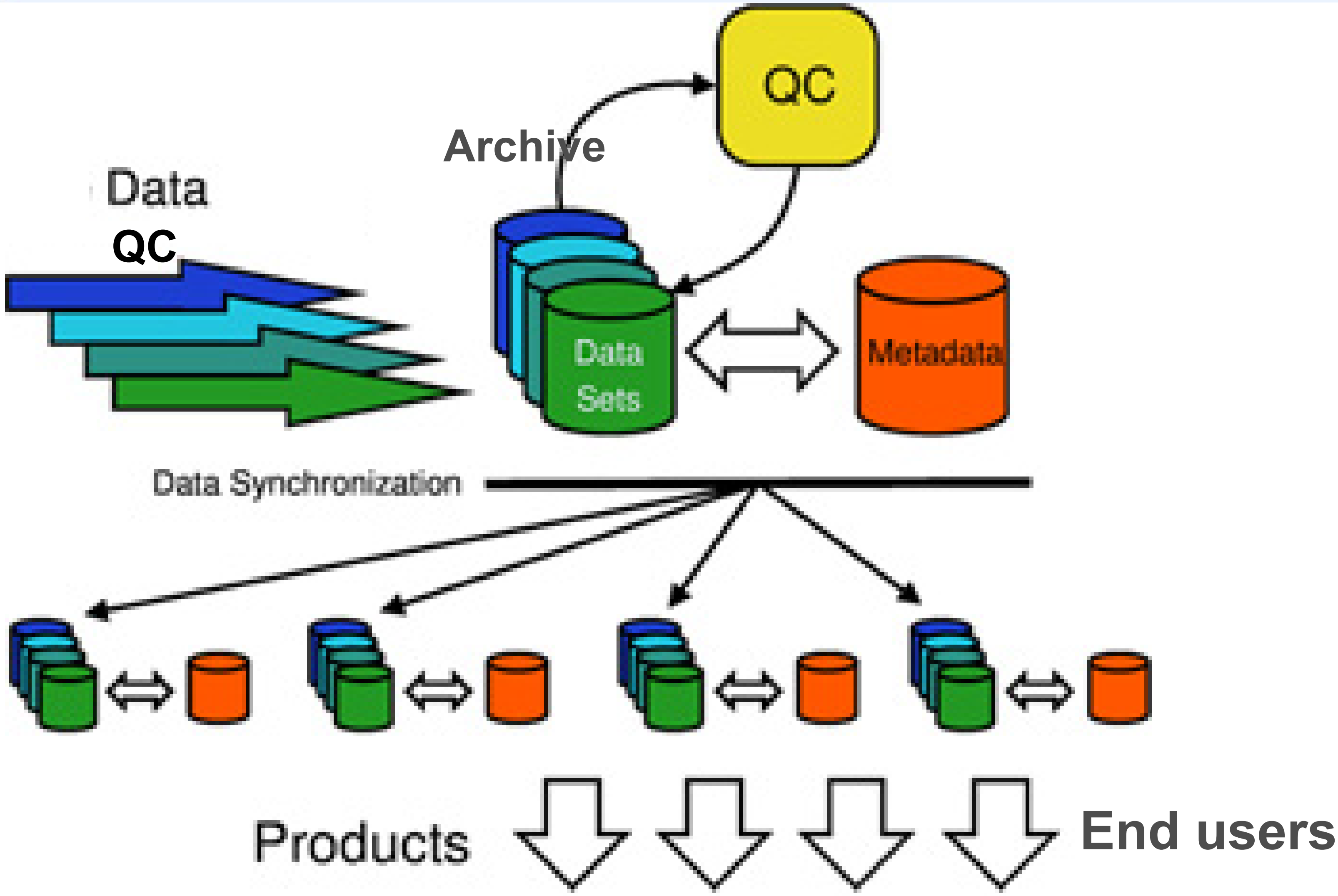
Past, present and future climate



Climate change is one of the biggest issues confronting humanity in the 21st century

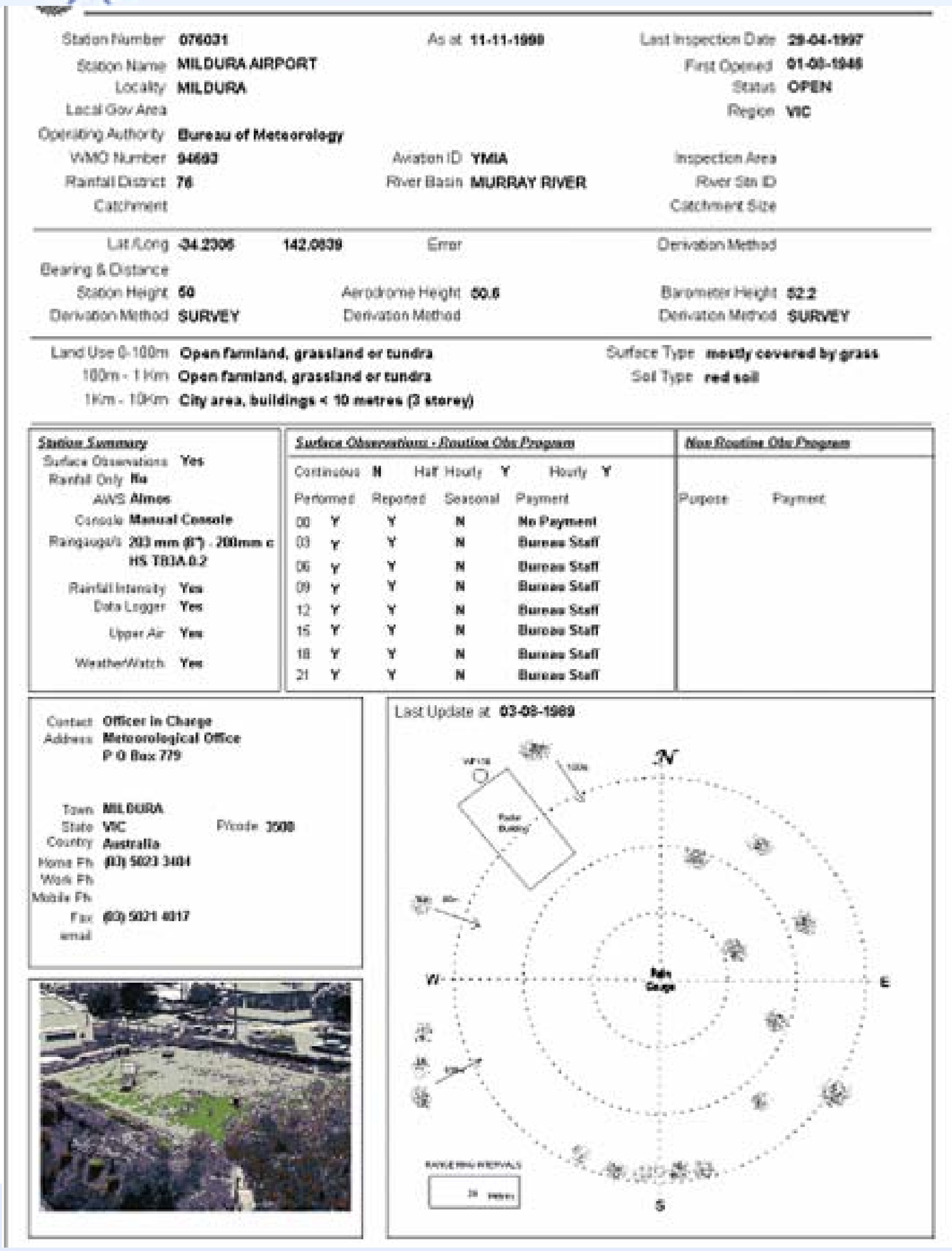
- **Climate is the averaged trend of weather, or the typically expected conditions**
- **Heat trapping gases emitted from human activities are driving significant changes in the climate**
- **Climate change magnifies existing health, environmental and social problems**

Data management system



Data quality control includes comparison to physical and climatological limits and inter-comparison of data elements.

Metadata (Data about data)



Station Number 076031 | As at 11-11-1998 | Last Inspection Date 29-04-1997

Station Name MILDURA AIRPORT | First Opened 01-08-1946

Locality MILDURA | Status OPEN

Local Gov Area | Region VIC

Operating Authority Bureau of Meteorology

WMO Number 94693 | Aviation ID YMIA | Inspection Area

Rainfall District 76 | River Basin MURRAY RIVER | River Stn ID

Catchment | Catchment Size

Lat/Long -34.2306 142.0839 | Error | Derivation Method

Bearing & Distance

Station Height 50 | Aerodrome Height 50.6 | Barometer Height 52.2

Derivation Method SURVEY | Derivation Method | Derivation Method SURVEY

Land Use 0-100m Open farmland, grassland or tundra | Surface Type mostly covered by grass

100m - 1 Km Open farmland, grassland or tundra | Soil Type red soil

1Km - 10Km City area, buildings < 10 metres (3 storey)

Station Summary

Surface Observations Yes

Rainfall Only No

AWS Almos

Console Manual Console

Raingauge/s 203 mm (8") - 200mm c HS TB3A 0.2

Rainfall Intensity Yes

Data Logger Yes

Upper Air Yes

WeatherWatch Yes

Surface Observations - Routine Obs Program

Continuous N | Half Hourly Y | Hourly Y

	Performed	Reported	Seasonal	Payment
00	Y	Y	N	No Payment
03	Y	Y	N	Bureau Staff
06	Y	Y	N	Bureau Staff
09	Y	Y	N	Bureau Staff
12	Y	Y	N	Bureau Staff
15	Y	Y	N	Bureau Staff
18	Y	Y	N	Bureau Staff
21	Y	Y	N	Bureau Staff

Non Routine Obs Program

Purpose | Payment

Contact Officer in Charge

Address Meteorological Office P O Box 779

Town MILDURA

State VIC | Pcode 3500

Country Australia

Home Ph (03) 5023 3404

Work Ph

Mobile Ph

Fax (03) 5021 4017

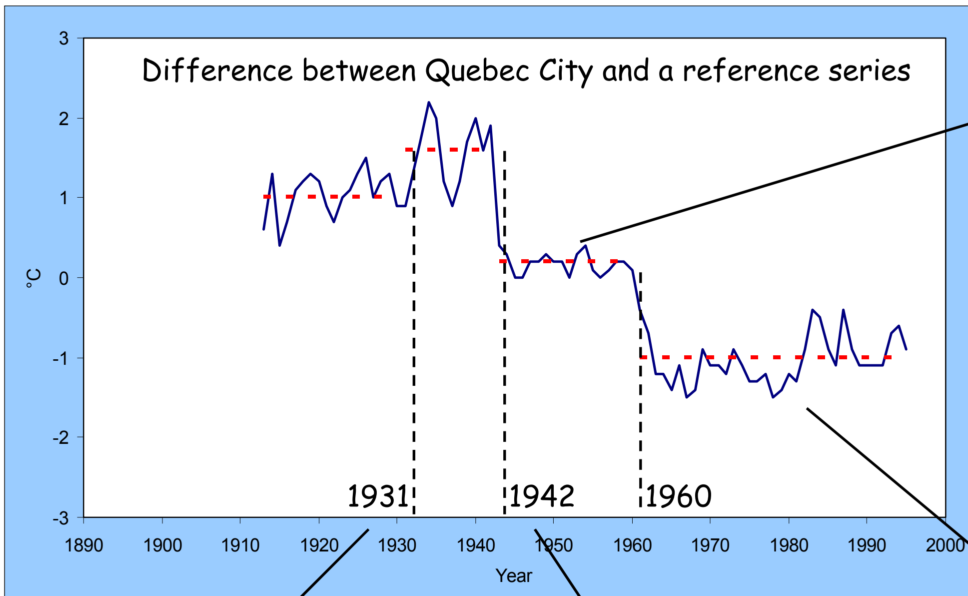
email

Last Update at 03-08-1989

Station documentation is information about the data or data about the data: Metadata should reflect how, where, when and by whom information was collected. Ideally, complete metadata should register all the changes a station has undergone during its lifetime, composing what is called the *station history.* Additional information about instrument or exposure, can provide additional insights. Sometimes when the instruments change, the observations will show an artificial increase or decrease. Such jump cause an inhomogeneity and adjustments needed to these data. If a long-term time series is homogeneous, then all variability and change is due to the behavior of the atmosphere. (By Aguilar, E., et al.)

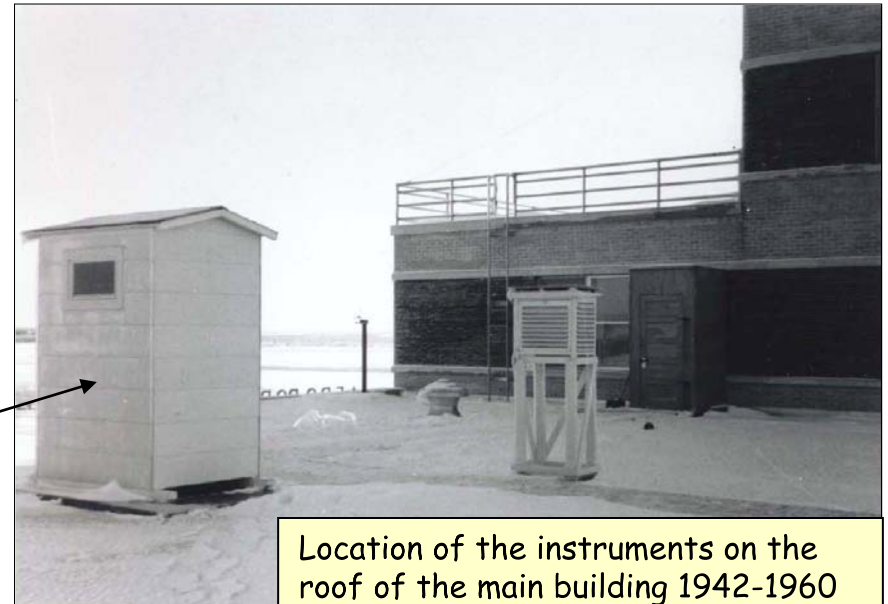
Homogeneity ← Metadata

Even if the small changes in the site locations can cause big breakpoints in the time series.

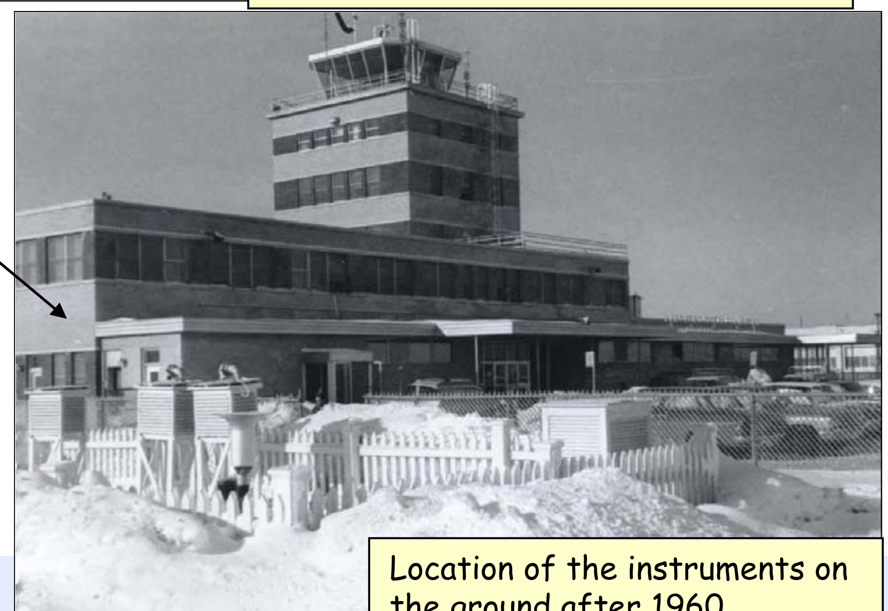


1931: relocation of the instruments at the college with change in exposure

1942: station relocation from college to airport



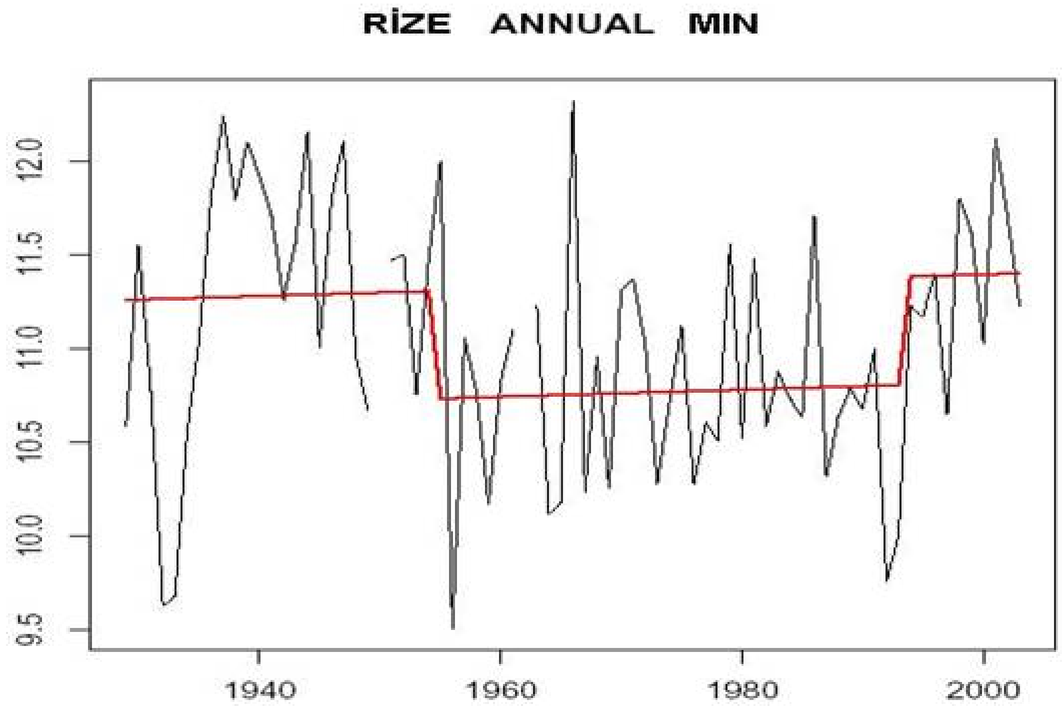
Location of the instruments on the roof of the main building 1942-1960



Location of the instruments on the ground after 1960

By Aguilar, E., et al.

Homogeneity test



Homogeneity test result of annual minimum temperature for station Rize, Turkey. The discontinuity in 1995 is reflected in metadata which shows that the station relocated in this year.

Data homogeneity is assessed using R-based program, RHtest, developed at the Meteorological Service of Canada. It is based on two-phase regression model with a linear trend for the entire base series (Wang, 2003). There is also cost action in homogenization http://www.homogenisation.org

Statistical process, estimation of missing data, Normal (are calculated from 1971-2000)

F8 fx =(F7+F10)/2

=(F6+F11)/2

=(J7+J9)/2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	İSTASYON	ELEMENT	YIL	OCK	SBT	MRT	[illegible]S	MAY	HAZ	T[illegible]M	AĞST	EYL	EKİM	KAS	ARA	YILLI
2	ACIPAYAM	ORT-SIC	1971	5.7	3.3	6.6	10.0	15.3	19.9	22.9	22.3	18.8	11.4	7.3	1.1	12.1
3	ACIPAYAM	ORT-SIC	1972	0.8	1.7	7.6	13.2	16.0	19.7	22.9	22.8	19.7	12.2	6.2	1.1	12.0
4	ACIPAYAM	ORT-SIC	1973	0.7	4.0	5.3	9.4	16.7	18.6	24.2	23.8	20.6	13.7	4.9	3.7	12.1
5	ACIPAYAM	ORT-SIC	1974	-0.9	3.3	8.5	9.6	15.5	21.7	24.5	22.4	18.3	15.7	7.1	1.9	12.3
6	ACIPAYAM	ORT-SIC	1975	1.7	1.7	7.2	11.8	14.5	18.8	24.3	23.1	19.2	13.1	6.5	1.7	12.0
7	ACIPAYAM	ORT-SIC	1976	0.0	0.2	6.5	9.7	15.1	19.3	22.0	21.3	17.5	14.3	7.9	3.4	11.4
8	ACIPAYAM	ORT-SIC	1977	1.3	5.8	7.3	10.3	16.3	19.9	23.5	21.8	17.5	14.3	6.8	3.4	12.3
9	ACIPAYAM	ORT-SIC	1978	1.8	5.7	6.3	10.8	17.4	20.4	25.0	22.3	17.4	14.2	5.7	3.4	12.5
10	ACIPAYAM	ORT-SIC	1979	2.2	5.6	8.0	10.8	14.5	19.6	23.0	22.9	19.9	14.1	7.7	3.3	12.6
11	ACIPAYAM	ORT-SIC	1980	0.3	2.6	5.3	9.7	15.2	21.0	25.0	24.1	18.1	14.2	8.5	3.8	12.3
12	ACIPAYAM	ORT-SIC	1981	1.9	2.5	7.8	10.7	13.5	20.6	23.6	22.6	19.4	15.1	5.7	6.2	12.5
13	ACIPAYAM	ORT-SIC	1982	3.2	0.8	5.0	10.6	15.1	19.9	21.4	23.1	19.2	12.8	5.4	3.1	11.6
14	ACIPAYAM	ORT-SIC	1983	-1.1	0.7	5.8	11.5	15.7	18.0	21.2	21.5	18.2	11.8	8.5	4.5	11.4
15	ACIPAYAM	ORT-SIC	1984	3.4	4.8	6.1	9.2	17.3	21.0	23.0	21.2	19.6	14.2	7.4	2.3	12.5
16	ACIPAYAM	ORT-SIC	1985	4.3	-0.6	6.0	12.1	16.8	20.8	23.2	24.8	19.5	10.9	9.3	3.5	12.6
17	ACIPAYAM	ORT-SIC	1986	3.8	4.7	7.9	13.3	13.8	19.9	25.0	24.5	19.1	12.3	4.7	1.7	12.6
18	ACIPAYAM	ORT-SIC	1987	3.3	4.3	2.4	9.0	15.1	20.4	24.9	23.4	21.0	12.4	6.5	3.9	12.2
19	ACIPAYAM	ORT-SIC	1988	3.4	3.0	4.1	11.6	17.5	21.6	26.0	23.7	19.5	12.1	4.7	3.7	12.6
20	ACIPAYAM	ORT-SIC	1989	-0.1	2.8	8.4	15.7	16.3	20.2	24.5	24.8	19.8	11.8	7.2	3.0	12.9
21	ACIPAYAM	ORT-SIC	1990	0.0	3.5	7.9	11.2	15.5	21.0	25.8	24.0	19.0	14.3	8.9	4.4	13.0
22	ACIPAYAM	ORT-SIC	1991	1.6	3.2	9.2	10.9	13.9	22.5	24.0	23.8	19.7	14.2	7.2	0.5	12.6
23	ACIPAYAM	ORT-SIC	1992	-1.9	-0.7	4.3	11.3	15.3	20.3	22.3	24.3	18.7	16.3	6.8	0.5	11.5
24	ACIPAYAM	ORT-SIC	1993	-0.1	1.2	5.6	11.3	14.3	21.0	24.3	25.2	19.9	16.0	7.0	5.0	12.6
25	ACIPAYAM	ORT-SIC	1994	4.5	3.8	7.1	13.0	17.2	21.3	24.2	24.8	22.9	15.8	6.6	2.3	13.6
26	ACIPAYAM	ORT-SIC	1995	3.8	5.6	6.2	9.7	16.8	22.9	23.3	24.5	20.6	12.8	4.9	4.7	13.0
27	ACIPAYAM	ORT-SIC	1996	1.9	5.1	5.3	9.4	18.0	22.1	25.9	25.0	18.4	12.1	9.3	6.6	13.3
28	ACIPAYAM	ORT-SIC	1997	3.6	2.6	4.3	7.0	17.8	21.4	24.2	21.7	18.5	13.6	8.7	4.8	12.4
29	ACIPAYAM	ORT-SIC	1998	2.9	4.9	3.9	12.9	15.7	21.2	25.6	26.3	19.5	14.8	9.6	4.3	13.5
30	ACIPAYAM	ORT-SIC	1999	4.3	3.8	7.3	12.0	18.4	20.8	24.8	24.6	19.7	15.4	9.0	6.0	13.8
31	ACIPAYAM	ORT-SIC	2000	-0.8	2.5	5.1	12.5	16.1	21.6	26.4	24.7	19.7	13.3	9.3	3.8	12.9
32	ACIPAYAM	ORT-SIC	71-00	1.8	3.1	6.3	11.0	15.9	20.6	24.0	23.5	19.3	13.6	7.2	3.4	12.5
33	ACIPAYAM	ORT-SIC	stdev	2.0	1.8	1.6	1.7	1.3	1.1	1.3	1.3	1.1	1.5	1.5	1.6	0.6
34	ACIPAYAM	ORT-SIC	CV	106.1	60.0	25.4	15.4	8.2	5.4	5.6	5.6	5.9	10.7	20.9	46.8	4.9

= mean (D2:O2)

estimated data

Reference: WMO No.100

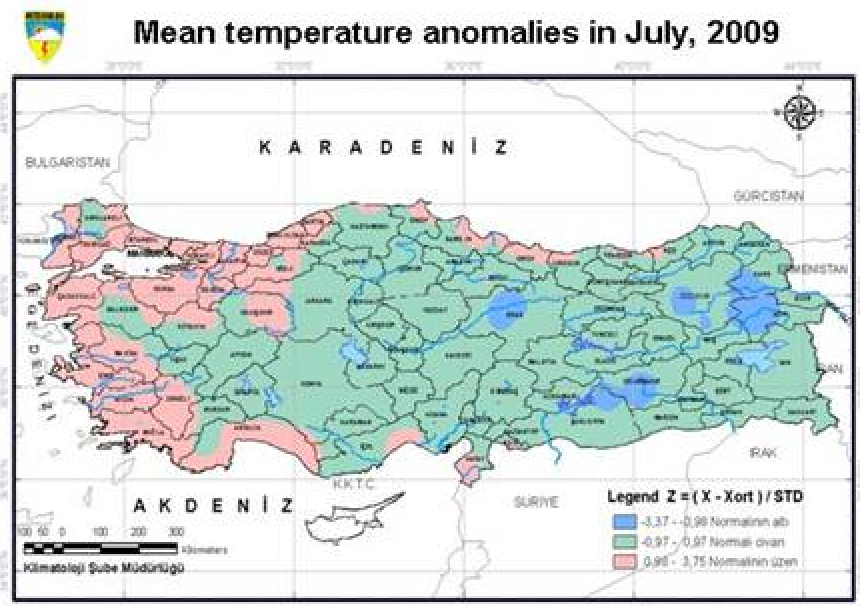
= mean (P2:P31)

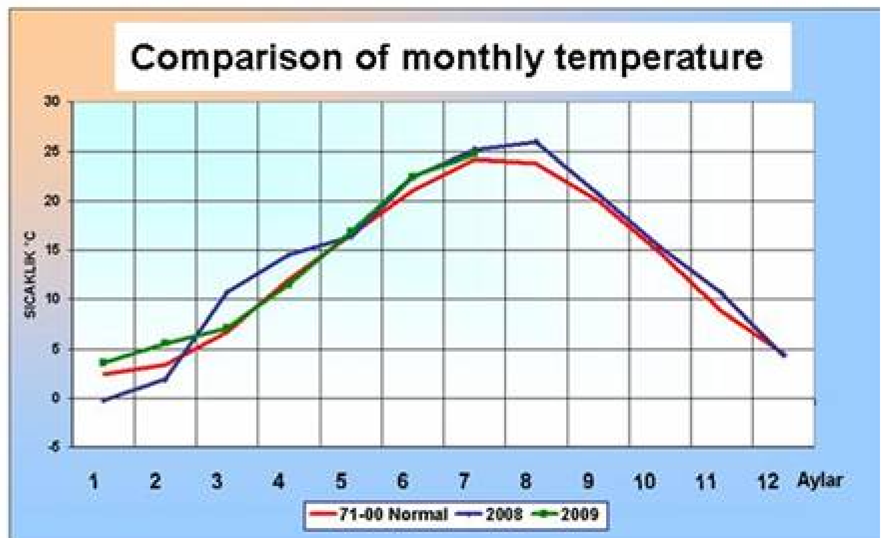
= STD (P2:P31)

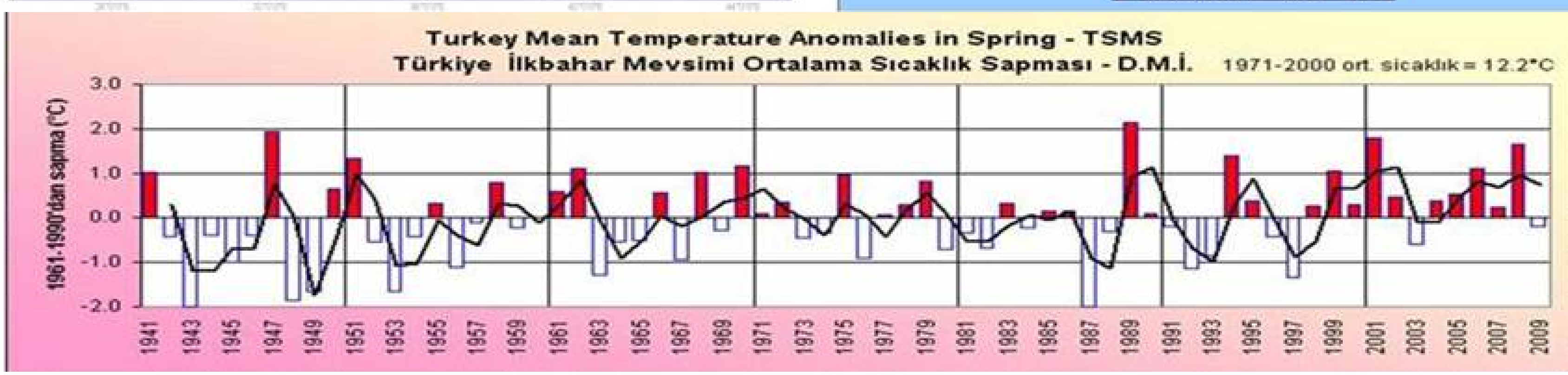
CV =(P33/P32)*100

Products-Monthly, seasonal and annual assessments

Anomaly detection is the traceability option of the data. **Anomaly** is the differences from normal and it is determining by using *Standardized Normal Distribution* which is formulated as **Z=(X-X mean) /STD**. If Z < -1 it means the data is below normal, if Z is in between -1 to 1, near normal, and if Z > 1 it means this value is over normal.







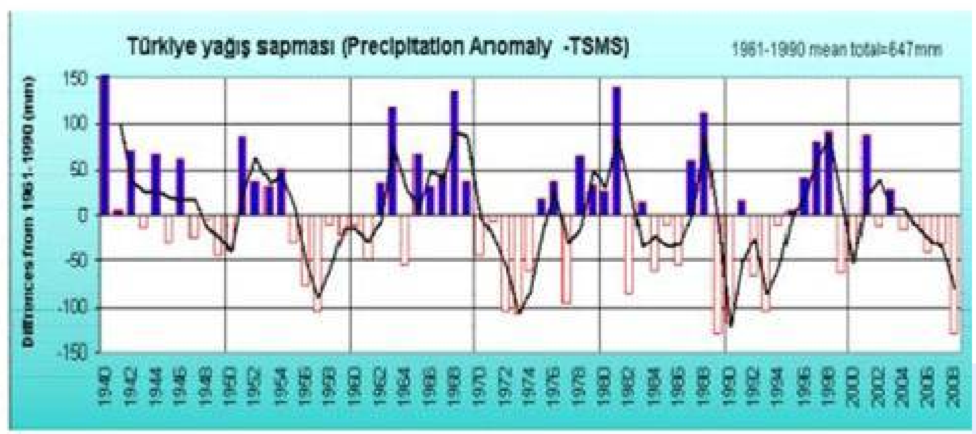
Products- Monitoring & Time series

Annual climate assessment

Maps and Time series are very good tools to trace spatial and temporal variation of data. Below there is an assessment for the year 2008. 2008 mean temperature was 0.8°C above the 1961-1990 normal (13.6°C). Generally coastal area and western part of the country had temperatures above the mean. Positive temperature anomalies have been occurred since 1994 (except 1997) (Fig. 1). This kind of analyses have been contributed to the “Statement on the Status of the Climate " which published by WMO and NOAA, BAMS

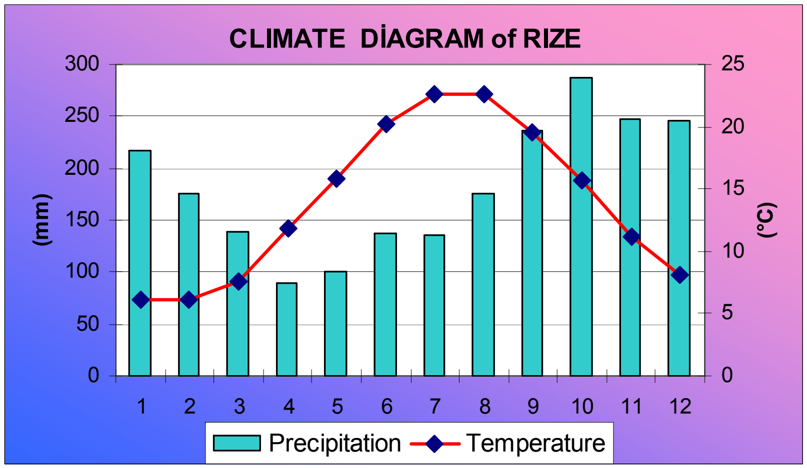
Mean temperature anomalies in 2008

Precipitation anomalies in 2008

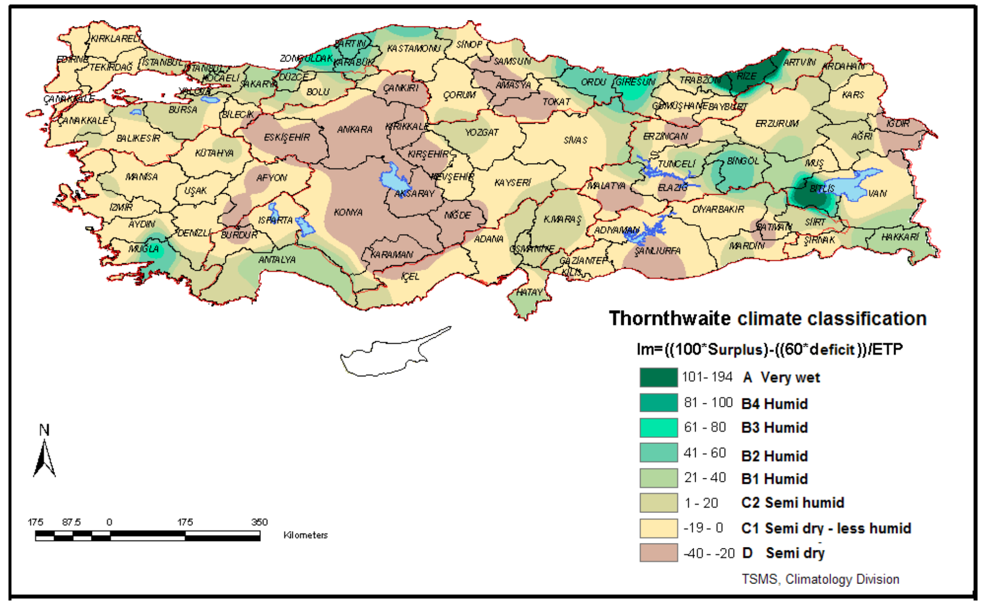


Products- Climate Diagram

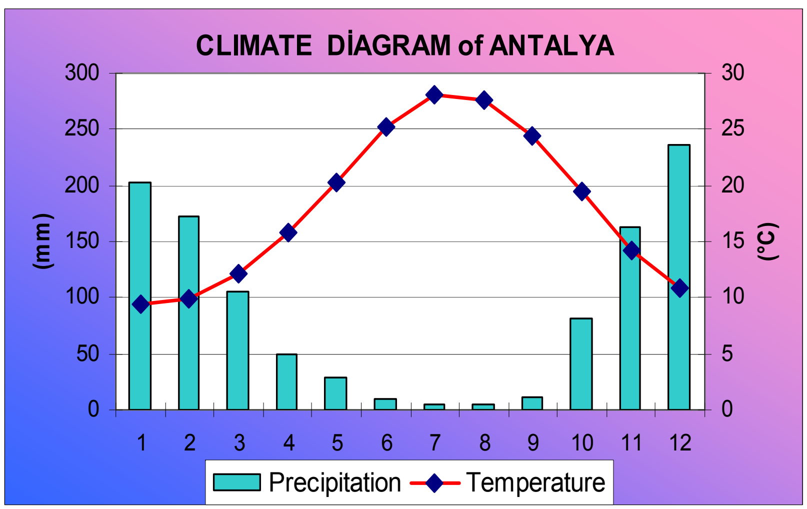
Climate Diagram is another traceability study which shows monthly variation on precipitation and temperature in the study area.



It's rainy in all season & very wet climate



Climate classification of Turkey by Thornthwaite



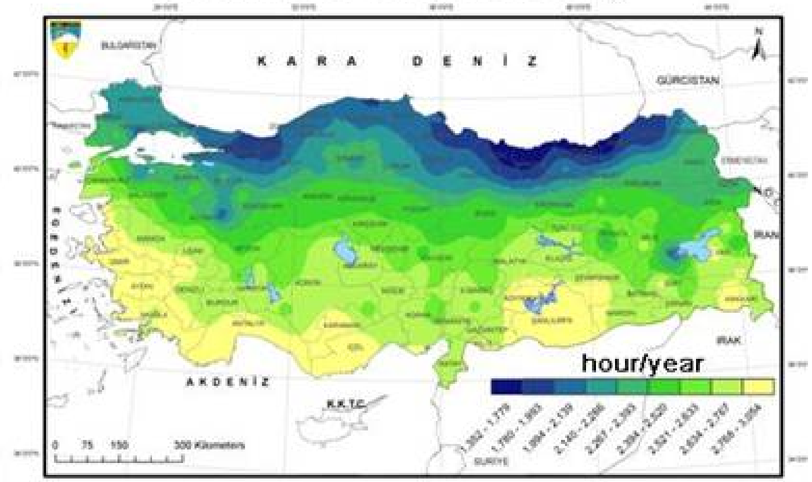
It's rainy in Winter but dry and hot in Summer (Mediterranean climate)

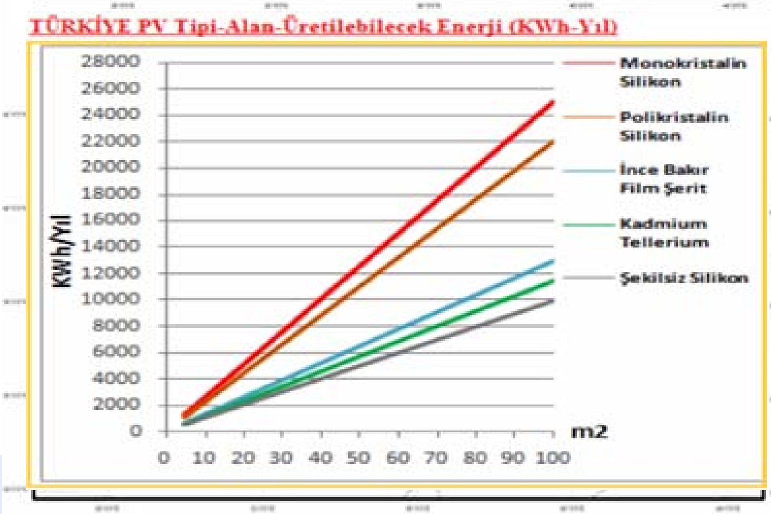
Products- Climate atlas

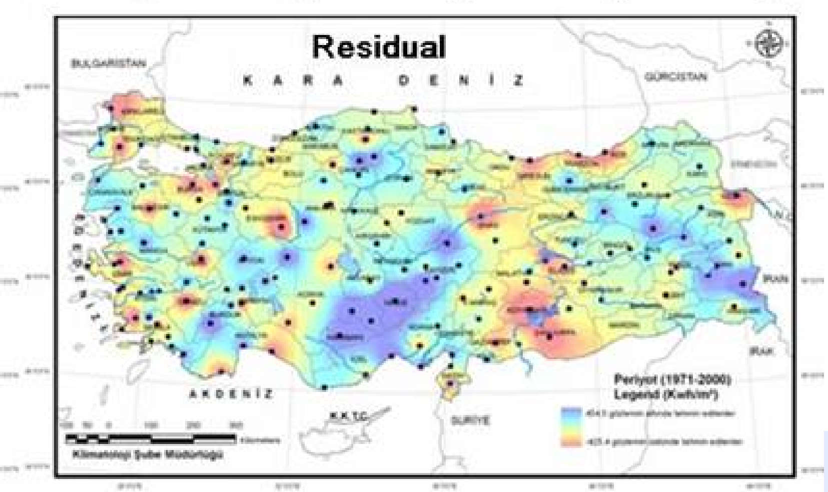
Climate atlas is another monitoring and traceability options. All the data used in the atlas have enough time length (at least 30 years) and must be quality controlled. Nowadays GIS techniques (Geostatistical analyze, Co-kriging, IDW, GWR) have been used For interpolation, modeling and monitoring the data.

Annual total radiation (1971-2000)
(Modelled via Geographically Weighted Regression)

Sunshine duration (1971-2000)

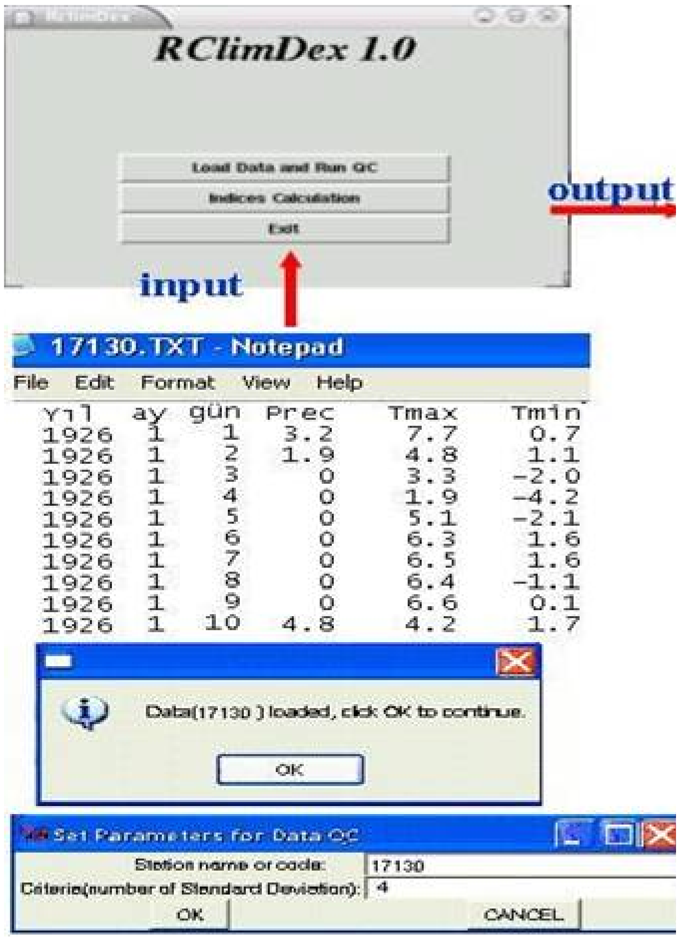






Climate Indices

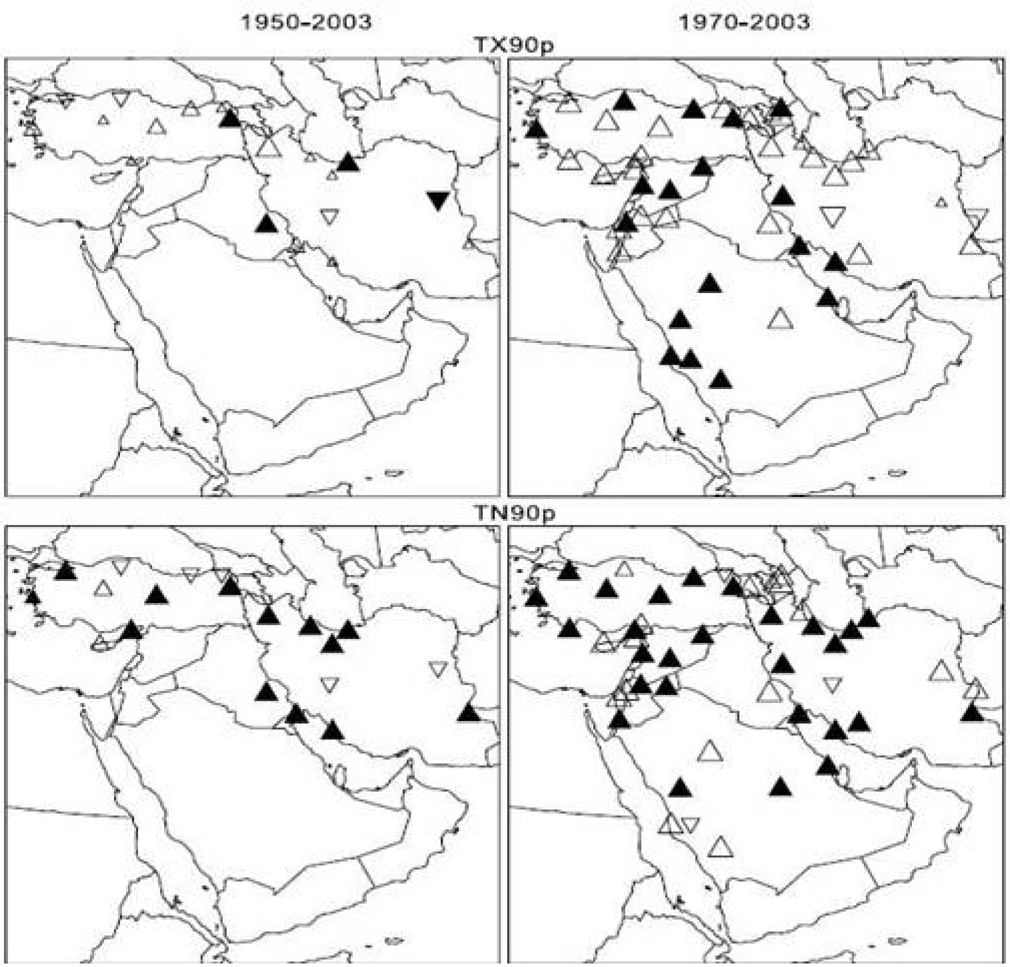
RClimDex produced on behalf of the ET by Xuebin Zhang from Met. Service of Canada
http://cccma.seos.uvic.ca/ETCCDMI/



APPENDIX A - List of the 27 core climate indices

No	ID	Indicator name	Definitions	UNITS
1	FD0	Frost days	Annual count when TN(daily minimum)<0℃	Days
2	SU25	Summer days	Annual count when TX(daily maximum)>25℃	Days
3	ID0	Ice days	Annual count when TX(daily maximum)<0℃	Days
4	TR20	Tropical nights	Annual count when TN(daily minimum)>20℃	Days
5	GSL	Growing season Length	Annual (1st Jan to 31^{st} Dec in NH, count between first span of at least 6 days with TG>5℃ and first span after July 1 of 6 days with TG<5℃	Days
6	TXx	Max Tmax	Monthly maximum value of daily maximum temp	℃
7	TNx	Max Tmin	Monthly maximum value of daily minimum temp	℃
8	TXn	Min Tmax	Monthly minimum value of daily maximum temp	℃
9	TNn	Min Tmin	Monthly minimum value of daily minimum temp	℃
10	TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
11	TX10p	Cool days	Percentage of days when TX<10th percentile	Days
12	TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
13	TX90p	Warm days	Percentage of days when TX>90th percentile	Days
14	WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
15	CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
16	DTR	Diurnal temperature	Monthly mean difference between TX and TN	℃
17	RX1day	Max 1-day precipitation	Monthly maximum 1-day precipitation	mm
18	Rx5day	Max 5-day precipitation	Monthly maximum consecutive 5-day precipitation	mm
19	SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day
20	R10	Number of heavy prec.	Annual count of days when PRCP>=10mm	Days
21	R20	Number of very heavy P	Annual count of days when PRCP>=20mm	Days
22	Rnn	Number of days above nn mm	Annual count of days when PRCP>=nn mm, nn is user defined threshold	Days
23	CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
24	CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
25	R95p	Very wet days	Annual total PRCP when RR>95^{th} percentile	mm
26	R99p	Extremely wet days	Annual total PRCP when RR>99^{th} percentile	mm
27	PRCPTOT	Annual total wet-day	Annual total PRCP in wet days (RR>=1mm)	mm

Middle East Climate Indices Study

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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 110, D22104, doi:10.1029/2005JD006181, 2005

Trends in Middle East climate extreme indices from 1950 to 2003

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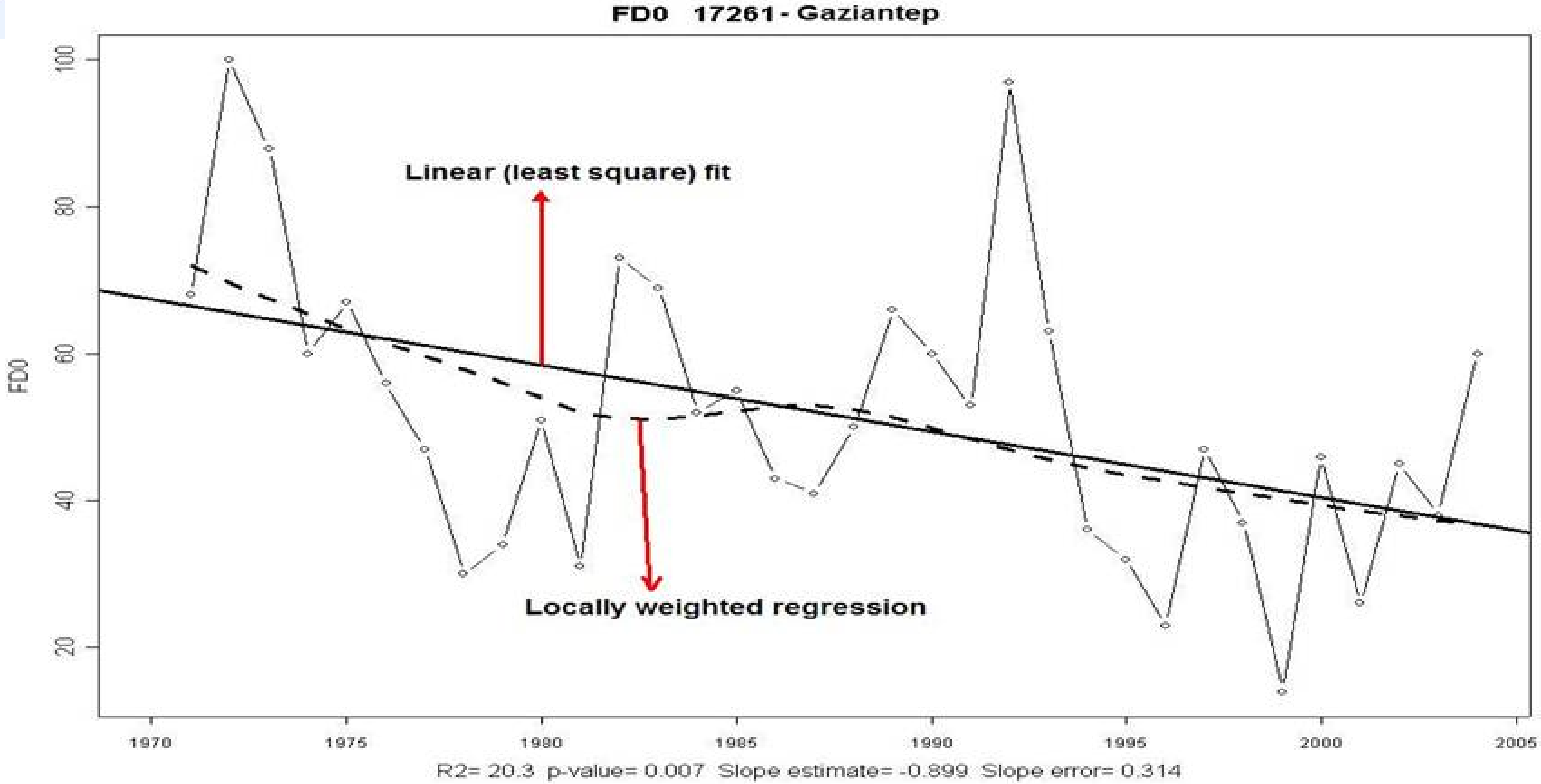
http://www.agu.org/pubs/crossref/2005/2005JD006181.shtml

It shows that warm nights and warm days have been increasing in the Middle East.

Indices plots and trend analysis



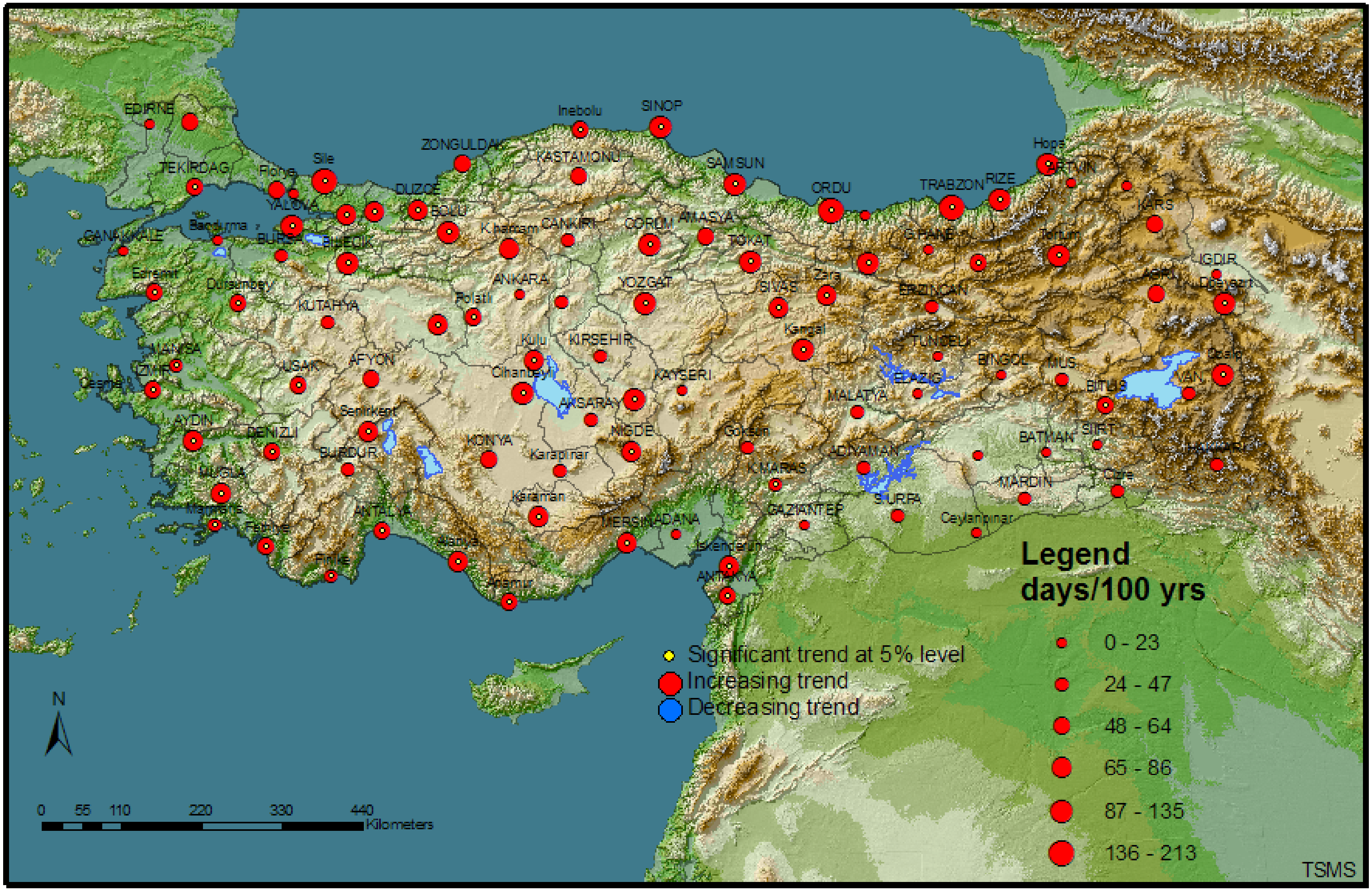
Kendall's tau based slope estimator has been used to compute the trends since this method doesn't assume a distribution for the residuals and is robust to the effect of outliers in the series. If slope error greater than slope estimate we can't trust slope estimate.

This indices plot shows that frost days will be decreasing 89.9 days in 100 years in Gaziantep and this trend is statistically significant at 95% level of confidence because of P Value is less than 0.05.

Advantages of Indices versus Data

- Indices are information derived from data
- It represents the data
- More readily released than data
- Useful in a wide variety of climate change analyses
- Useful for Model – observations comparisons
- Useful for analyses of extremes
- They can be more accessible than data (exchangeable)

Climate indices continued

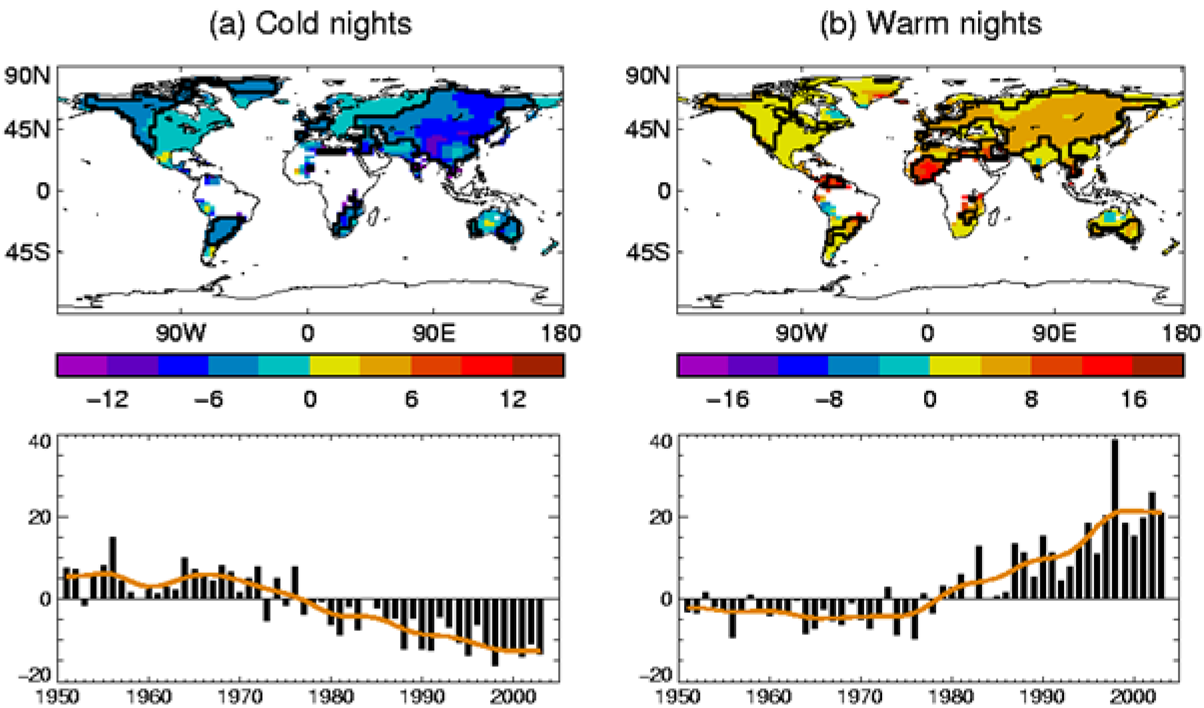


Trends in Number of Summer Days from 1971 to 2004 [Tx > 25°C]

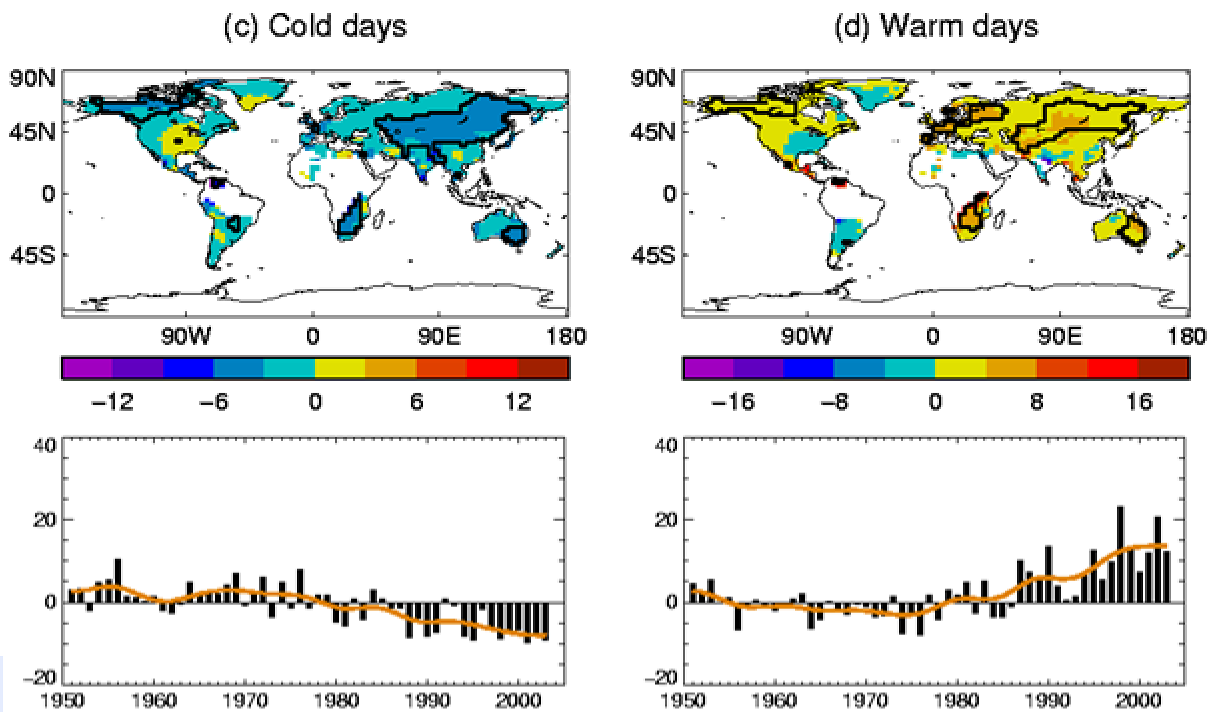
Numbers of Summer Days have been increasing all over Turkey.

Global Indices Analyses

By Alexander, L. et al

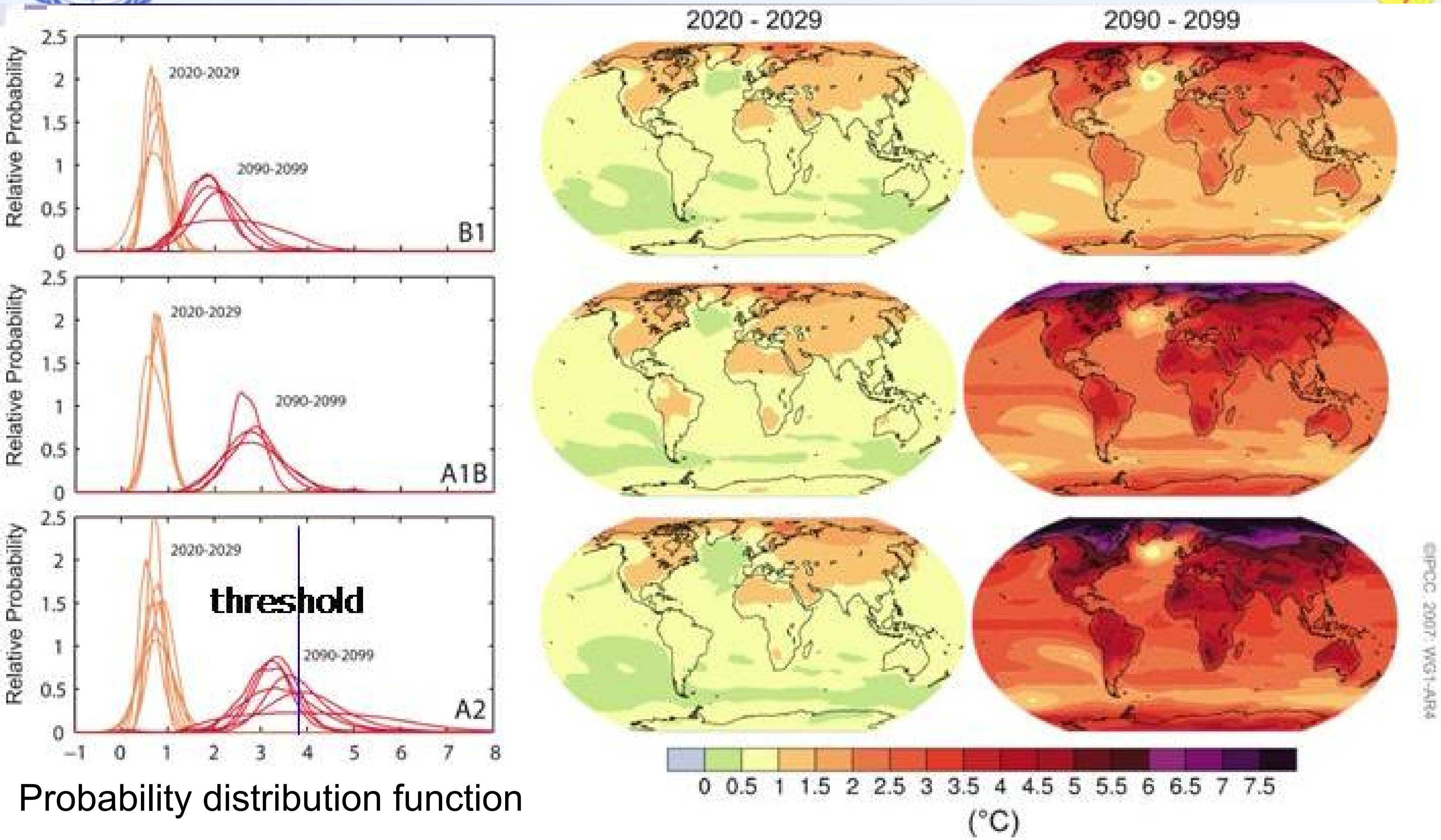


Trends in
(a) cold nights (TN10p),
(b) warm nights (TN90p),
(c) cold days (TX10p) and
(d) warm days (TX90p).



Trends were calculated only for the grid boxes with sufficient data (at least 40 years of data. Black lines enclose regions where trends are significant at the 95% confidence of level. The red curves on the plots are non-linear trend estimates obtained by smoothing using a 21-term binomial filter.

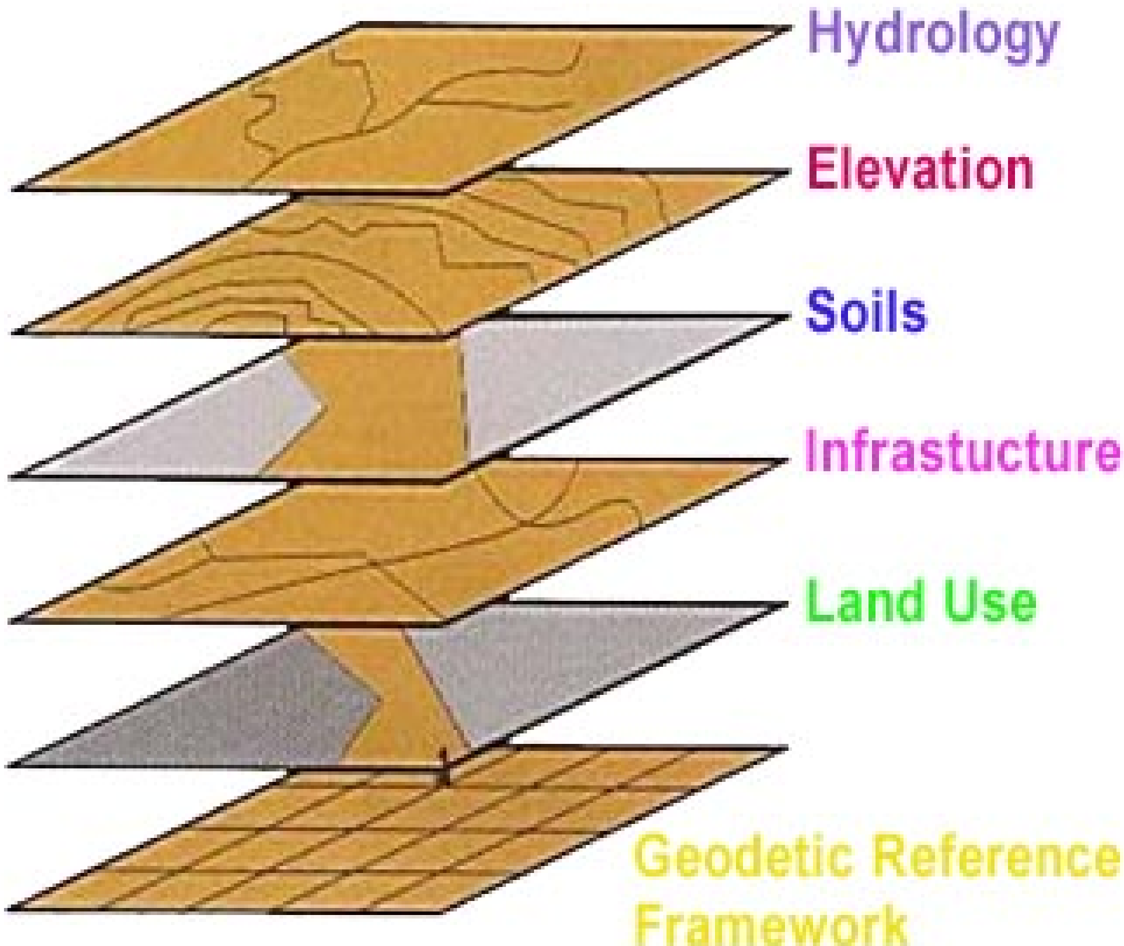
IPCC 2007, Temperature Projections



Probability distribution function

Projected surface temperature changes for the early and late 21st century.
If the PDF is widespread, it means that too many extreme event could be occurred.

Geographic Information System (GIS)



GIS isn't only monitoring software, it's capable to combine all kind of geographically referenced data, (vector, table, satellite, raster, proxy, etc) and to analyze, to select, to model and to monitor them.

Conclusion

✓Climate system is comprised by the complicated interactions among the atmosphere, the ocean, the cryosphere, the surface lithosphere and the biosphere.

✓Long time reliable climate observation and information are necessary to detect climate variability and change and to help decision makers to mitigate and adaptation

✓Climate data needs to undertake quality control, homogeneity assessment, data rescue and statistical process in order to produce reliable climate information and products.

✓There are still huge amount of historical climate data which need to rescue and digitization.

✓Climate indices also very useful tool to detect climate variability and to understand trends in the extreme.

✓GIS is also very useful tool for traceability. It's not only monitoring software, it's capable to combine all kind of geographically referenced data, (vector, table, satellite, raster, proxy, etc) and to analyze, to select, to model and to monitor them.

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Acknowledgement

I appreciate The GEO Secretariat, who funded my mission.

I would like to acknowledge the following scientist and centers for their contributions.

Dr. Thomas C. Peterson, NOAA, NCDC, USA
Dr. Lisa V. Alexander, University of Sydney, Australia
Dr. Enric Aguilar, *University Rovira i Virgili, Tarragona, Spain*
Dr. Manola Brunet, University Rovira i Virgili, Tarragona, Spain
CM-SAF, GCOS, IPCC, MEDARE, NOAA

I would like to acknowledge Mr. Mehmet Çağlar, Director-General and PR of Turkey with WMO for his concurrence

Thanks for your Attention

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