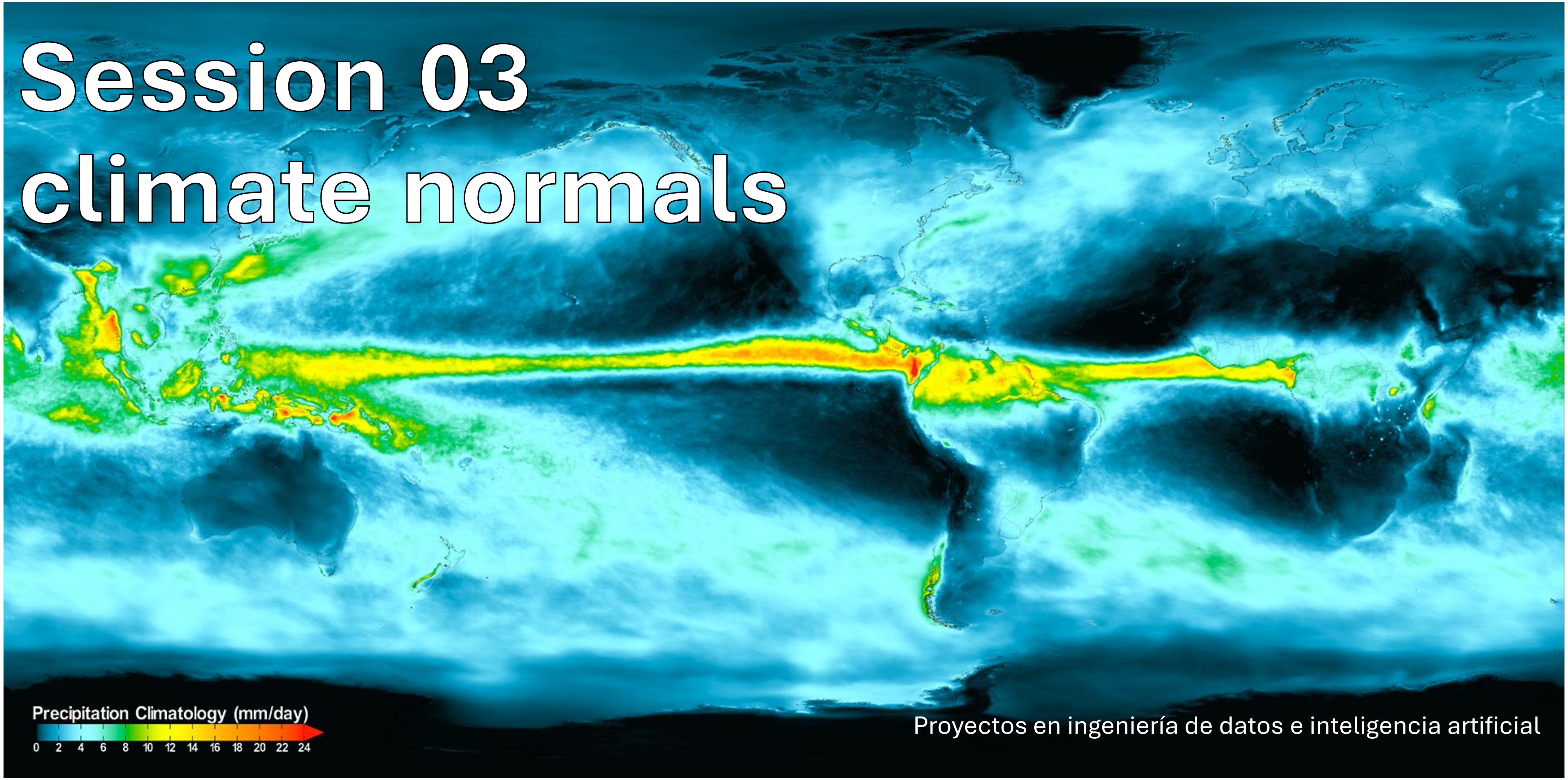
Session 03
climate normals



Proyectos en ingeniería de datos e inteligencia artificial

You will be able to

- Understand the fundamentals of climate normals.
- Calculate a climatology using long-term precipitation data from satellite + ground based observations

The problem

The City of Seattle is undertaking a comprehensive review of its stormwater management systems in response to increasing concerns about urban flooding and climate variability. Although Seattle is known for its frequent rainfall, recent years have shown shifts in precipitation intensity and seasonal distribution, prompting the need for updated infrastructure planning.

The approach

Use **long-term climate data** (30-year average) to characterize the typical rainfall pattern.

What are climate normals?

A long-term statistical baseline or reference model from historical data

What are climate normals?

In climate science, climate normals represent the average state of the atmosphere over a long-term period.

Principal climatological surface parameters		
Parameter	*Units*	*Comments*
Precipitation total	mm	Definition of observation day should be according to national standards and documented in metadata (see also section 4.9)
Number of days with precipitation ≥ 1 mm	count	
Monthly mean values of maximum, minimum and daily mean temperatures	°C	Definition of observation day, and the way in which daily mean temperature is calculated, should be according to national standards and documented in metadata (see also section 4.9). Different methods are in operational use for the calculation of daily mean temperature.
Mean value of sea-level pressure	hPa	Daily values should be calculated, if possible, as the mean of either eight evenly spaced 3-hourly observations or four evenly spaced 6-hourly observations. If this is not possible, they should use a set of observation times that is consistent over time at that station and documented in metadata. At high-elevation stations, mean geopotential height at a set pressure level (for example, 850 hPa or 700 hPa) may be used as a substitute for mean sea-level pressure.
Mean vapour pressure	hPa	Should be calculated as the mean of daily values. Daily values should be calculated, if possible, as the mean of either eight evenly spaced 3-hourly observations or four evenly spaced 6-hourly observations. If this is not possible, they should use a set of observation times that is consistent over time at that station and documented in metadata. It is important that monthly means of vapour pressure are calculated from daily values of vapour pressure and not from monthly means of relative humidity or dewpoint temperature, as those methods will give different results.
Total number of hours of sunshine	hours	

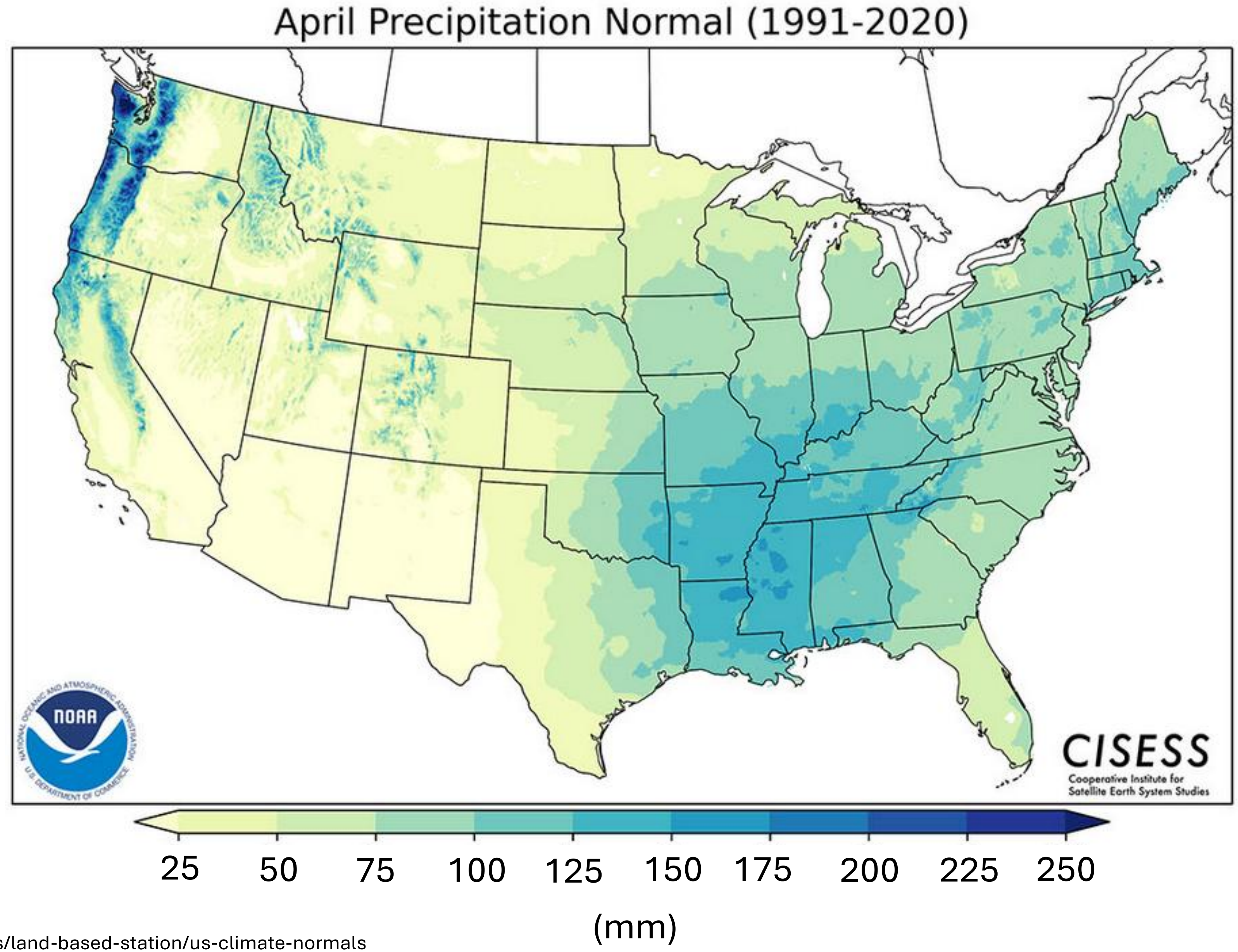
Why construct climate normals?

Provides a reference state of the atmosphere/whatever based on long-term averages.

Why construct climate normals?

Provides a reference state of the atmosphere/whatever based on long-term averages.

- **Defines what is “normal” for a region or season** [get reference data]
- Detect changes in current state [causal filter]
- Quantify deviations from the norm [anomaly detection]



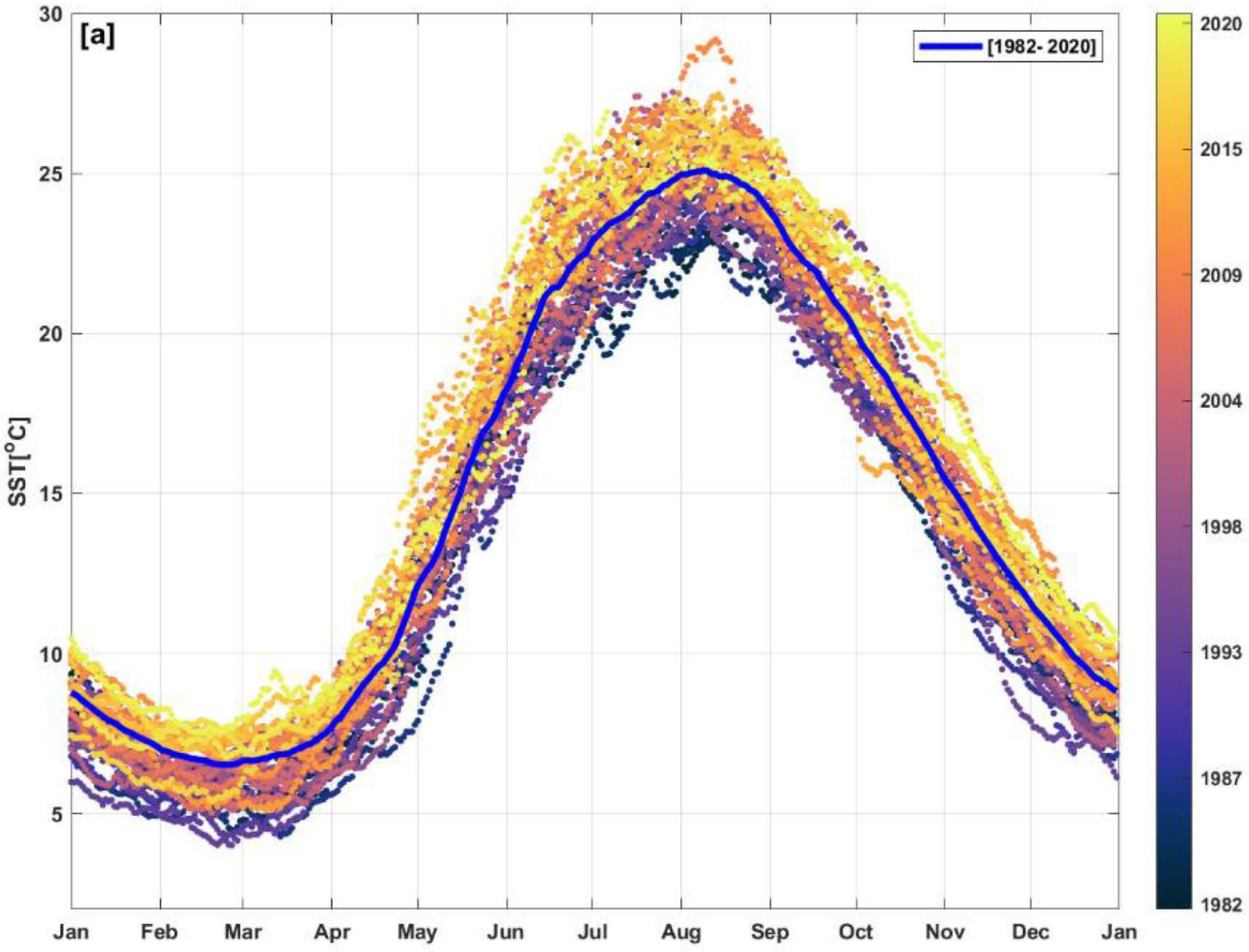
https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals

Why construct climate normals?

Provides a reference state of the atmosphere/whatever based on long-term averages.

- Defines what is "normal" for a region or season [get reference data]
- **Detect changes in current state** [causal filter]
- Quantify deviations from the norm [anomaly detection]

Annual cycle for the mean Black Sea SST from 1982 to 2020. Each line represents a year in the study period, and the solid black line indicates the climatic mean.

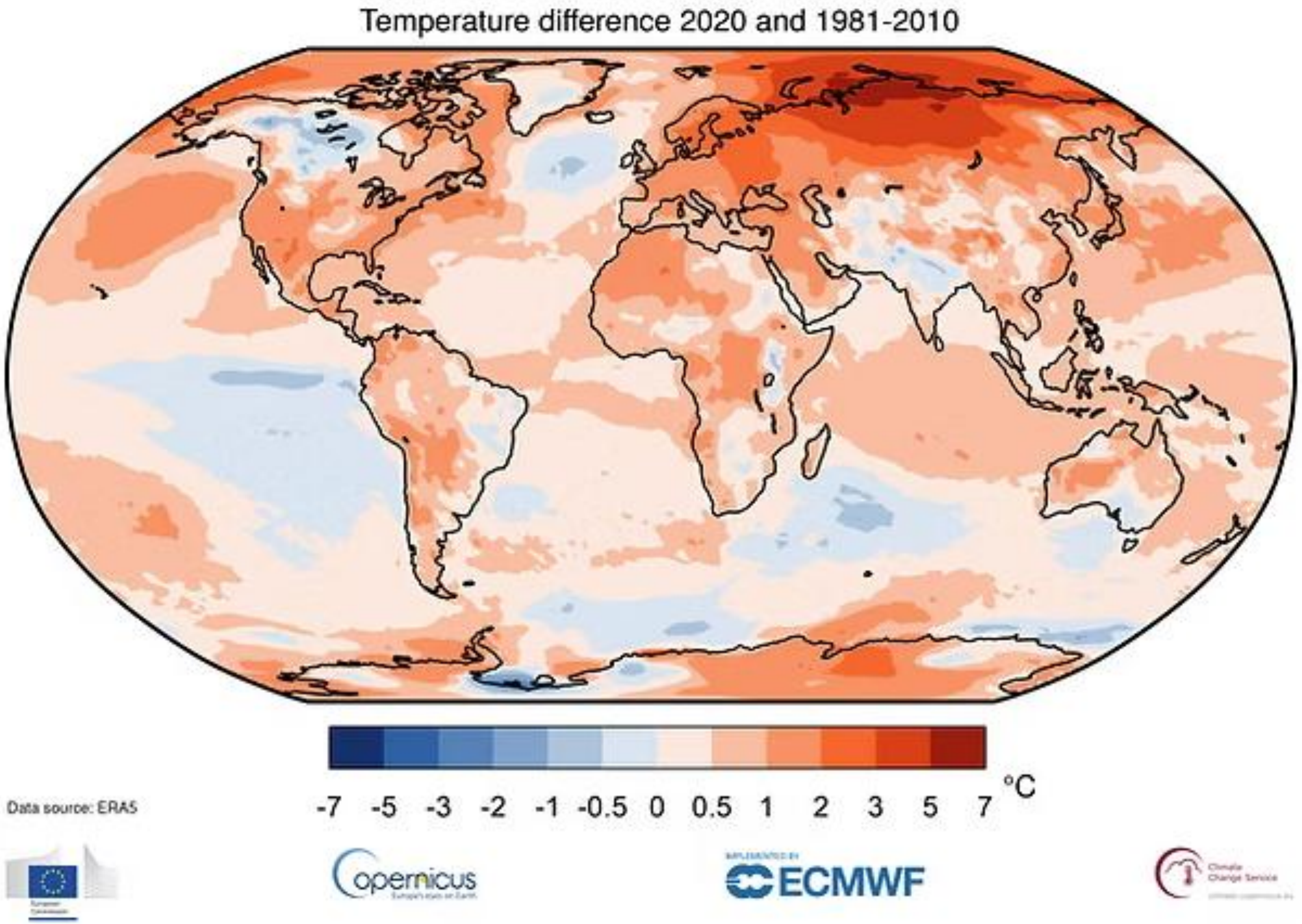


https://doi.org/10.3390/rs14102383

Why construct climate normals?

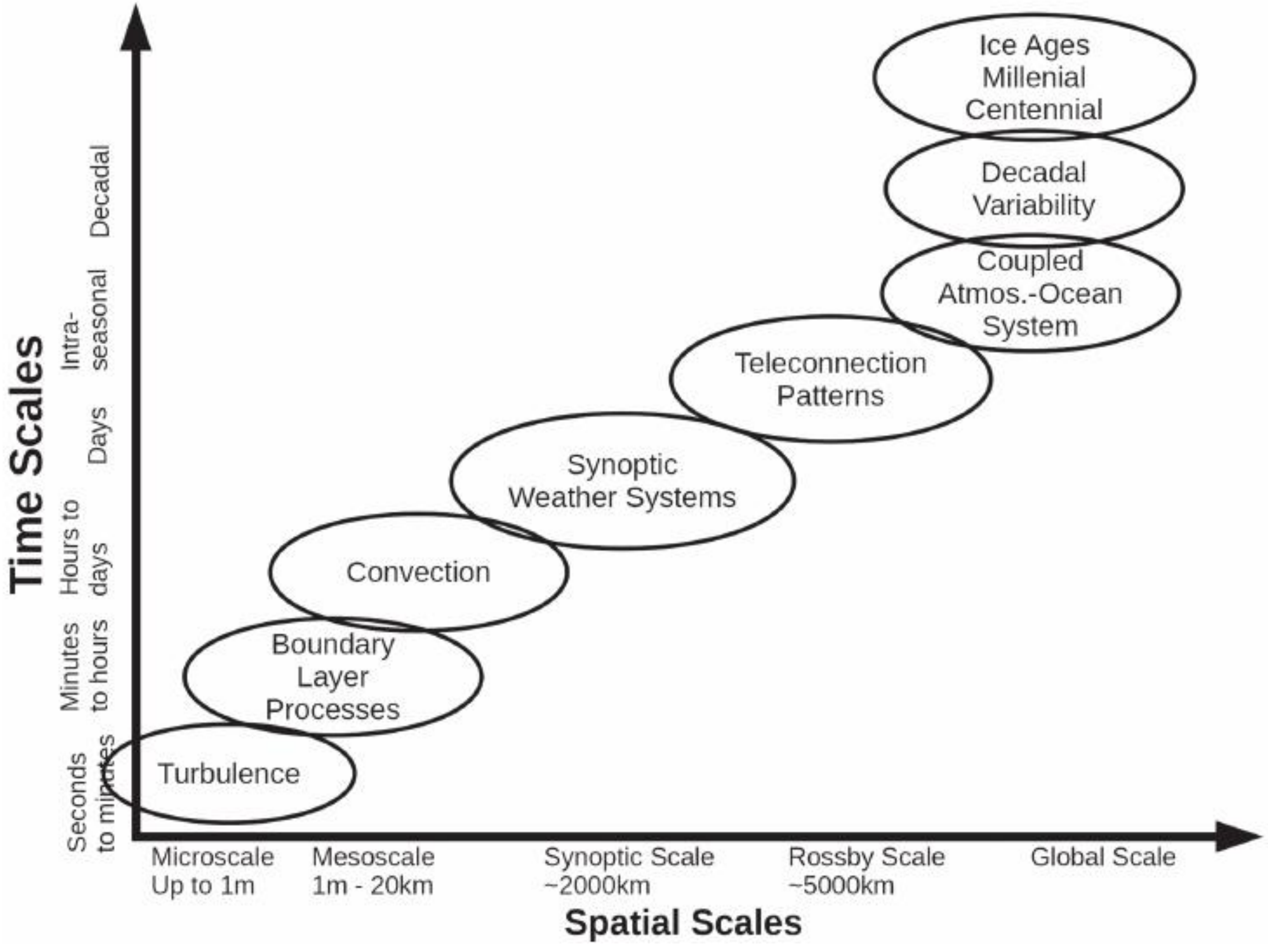
Provides a reference state of the atmosphere/whatever based on long-term averages.

- Defines what is “normal” for a region or season [get reference data]
- Detect changes in current state [causal filter]
- **Quantify deviations from the norm** [anomaly detection]


Temperature difference 2020 and 1981-2010
-7 -5 -3 -2 -1 -0.5 0 0.5 1 2 3 5 7
°C
Data source: ERA5
opernicus
ECMWF

Why 30 years?

Why 30 years?



Schematic diagram of important spatial and temporal scales in the climate system. The solid lines denote an estimate of the relative variance of climate variability. The dashed lines denote the variance contribution to the total variance from climatic processes with characteristic spatial scales smaller than those indicated on the x axis. The periodic climate components are denoted by spikes of arbitrary width. See Mitchell (1976) for more details.

Limitations

This is the most common metric but it is also imperfect.

- Assumes stationary behavior [masking hidden tendencies]
- Applies the same procedures to any variable [each variable has different statistical characteristics]

Climate normals for different variables

Climate Variable	Observed Trend	Seasonality	Autocorrelation	Normal Calculation Recommendations	Suggested Alternative Method
Temperature	High (↑)	High	High	Shorter averages (10–15 years), weighted	Hinge Fit, OCN, linear regression
Precipitation	Low/Moderate	High	Low/Moderate	Longer averages (30–40 years), median	Median, OCN with N ≈ 15–20 yr
Atmos. Pressure	Low	Moderate	High	Stable, 30-year average acceptable	Classic or smoothed average
Relative Humidity	Variable	High	High	Depends on region; check local trend	Weighted average if trend exists
Wind Speed	Low/Moderate	Moderate	Low	High interannual variability; moving windows	Smoothed filter, EMD

OCN (Optimal Climate Normals): Selects the best averaging period based on predictive skill.
EMD (Empirical Mode Decomposition): Useful for nonlinear and nonstationary time series.
Hinge Fit: Effective when there is a clear structural change in the time series (e.g., post-1975 warming).

Implications of autocorrelation for climate normals

Autocorrelation in a climate time series refers to how much current values are statistically related to past values. This has several important implications when calculating climate normals:

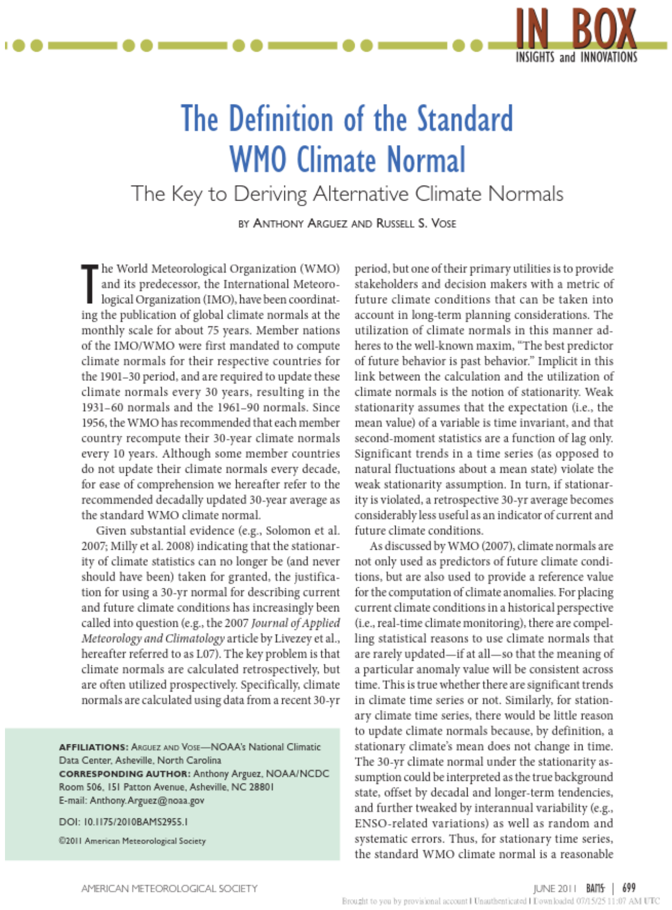
- Reduced effective sample size [points are not independent]
- Bias in the mean estimate [overestimate/underestimate]
- Persistence of anomalies [distortion of the mean values]

Implications of a trend for climate normals

A **trend** refers to a long-term increase or decrease in a climate variable over time — for example, the steady rise in global temperatures due to climate change

- Violates the stationary assumption [less representative of present/future conditions]
- Biases anomaly calculation [distort the interpretation of anomalies]
- Reduces predictive value

More on climate normals



IN BOX
INSIGHTS and INNOVATIONS

The Definition of the Standard WMO Climate Normal

The Key to Deriving Alternative Climate Normals

BY ANTHONY ARGUEZ AND RUSSELL S. VOSE

The World Meteorological Organization (WMO) and its predecessor, the International Meteorological Organization (IMO), have been coordinating the publication of global climate normals at the monthly scale for about 75 years. Member nations of the IMO/WMO were first mandated to compute climate normals for their respective countries for the 1901–30 period, and are required to update these climate normals every 30 years, resulting in the 1931–60 normals and the 1961–90 normals. Since 1956, the WMO has recommended that each member country recompute their 30-year climate normals every 10 years. Although some member countries do not update their climate normals every decade, for ease of comprehension we hereafter refer to the recommended decadally updated 30-year average as the standard WMO climate normal.

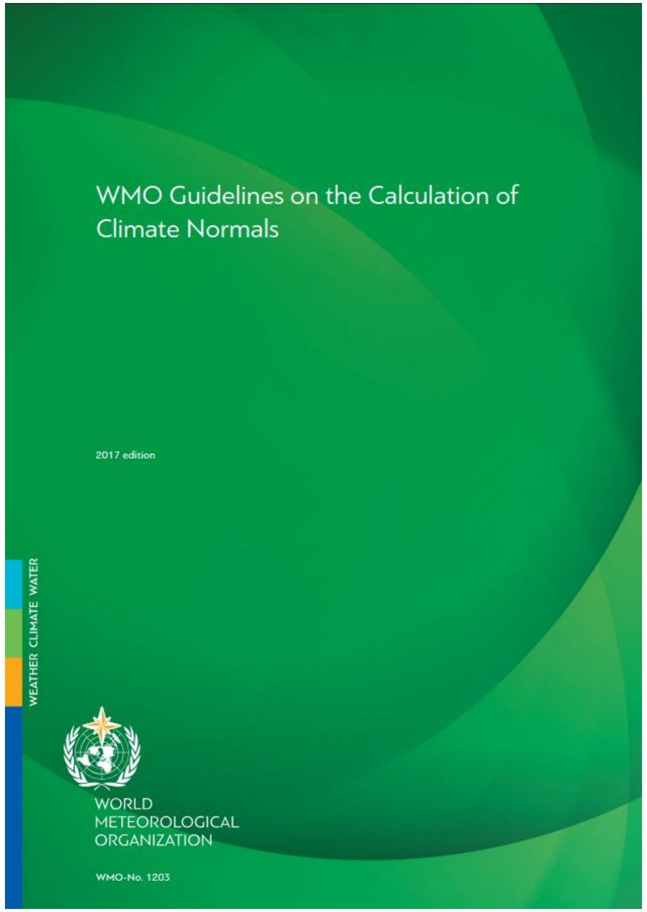
Given substantial evidence (e.g., Solomon et al. 2007; Milly et al. 2008) indicating that the stationarity of climate statistics can no longer be (and never should have been) taken for granted, the justification for using a 30-yr normal for describing current and future climate conditions has increasingly been called into question (e.g., the 2007 *Journal of Applied Meteorology and Climatology* article by Livezey et al., hereafter referred to as L07). The key problem is that climate normals are calculated retrospectively, but are often utilized prospectively. Specifically, climate normals are calculated using data from a recent 30-yr period, but one of their primary utilities is to provide stakeholders and decision makers with a metric of future climate conditions that can be taken into account in long-term planning considerations. The utilization of climate normals in this manner adheres to the well-known maxim, "The best predictor of future behavior is past behavior." Implicit in this link between the calculation and the utilization of climate normals is the notion of stationarity. Weak stationarity assumes that the expectation (i.e., the mean value) of a variable is time invariant, and that second-moment statistics are a function of lag only. Significant trends in a time series (as opposed to natural fluctuations about a mean state) violate the weak stationarity assumption. In turn, if stationarity is violated, a retrospective 30-yr average becomes considerably less useful as an indicator of current and future climate conditions.

As discussed by WMO (2007), climate normals are not only used as predictors of future climate conditions, but are also used to provide a reference value for the computation of climate anomalies. For placing current climate conditions in a historical perspective (i.e., real-time climate monitoring), there are compelling statistical reasons to use climate normals that are rarely updated—if at all—so that the meaning of a particular anomaly value will be consistent across time. This is true whether there are significant trends in climate time series or not. Similarly, for stationary climate time series, there would be little reason to update climate normals because, by definition, a stationary climate's mean does not change in time. The 30-yr climate normal under the stationarity assumption could be interpreted as the true background state, offset by decadal and longer-term tendencies, and further tweaked by interannual variability (e.g., ENSO-related variations) as well as random and systematic errors. Thus, for stationary time series, the standard WMO climate normal is a reasonable

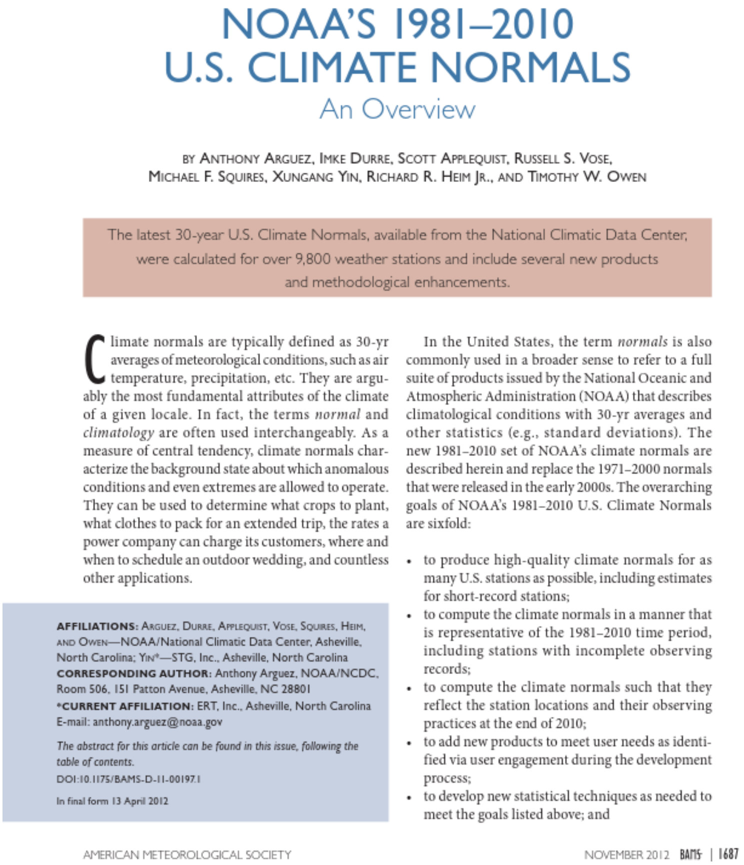
AFFILIATIONS: ARGUEZ AND VOSE—NOAA's National Climatic Data Center, Asheville, North Carolina
CORRESPONDING AUTHOR: Anthony Arguez, NOAA/NCDC Room 506, 151 Patton Avenue, Asheville, NC 28801
E-mail: Anthony.Arguez@noaa.gov

DOI: 10.1175/2010BAMS2955.1

https://doi.org/10.1175/2010BAMS2955.1



https://library.wmo.int/idurl/4/55797



NOAA'S 1981–2010 U.S. CLIMATE NORMALS

An Overview

BY ANTHONY ARGUEZ, IMKE DURRE, SCOTT APPLEQUIST, RUSSELL S. VOSE, MICHAEL F. SQUIRES, XUNGANG YIN, RICHARD R. HEIM JR., AND TIMOTHY W. OWEN

The latest 30-year U.S. Climate Normals, available from the National Climatic Data Center, were calculated for over 9,800 weather stations and include several new products and methodological enhancements.

Climate normals are typically defined as 30-yr averages of meteorological conditions, such as air temperature, precipitation, etc. They are arguably the most fundamental attributes of the climate of a given locale. In fact, the terms *normal* and *climatology* are often used interchangeably. As a measure of central tendency, climate normals characterize the background state about which anomalous conditions and even extremes are allowed to operate. They can be used to determine what crops to plant, what clothes to pack for an extended trip, the rates a power company can charge its customers, where and when to schedule an outdoor wedding, and countless other applications.

In the United States, the term *normals* is also commonly used in a broader sense to refer to a full suite of products issued by the National Oceanic and Atmospheric Administration (NOAA) that describes climatological conditions with 30-yr averages and other statistics (e.g., standard deviations). The new 1981–2010 set of NOAA's climate normals are described herein and replace the 1971–2000 normals that were released in the early 2000s. The overarching goals of NOAA's 1981–2010 U.S. Climate Normals are sixfold:

- to produce high-quality climate normals for as many U.S. stations as possible, including estimates for short-record stations;
- to compute the climate normals in a manner that is representative of the 1981–2010 time period, including stations with incomplete observing records;
- to compute the climate normals such that they reflect the station locations and their observing practices at the end of 2010;
- to add new products to meet user needs as identified via user engagement during the development process;
- to develop new statistical techniques as needed to meet the goals listed above; and

AFFILIATIONS: ARGUEZ, DURRE, APPLEQUIST, VOSE, SQUIRES, HEIM, AND OWEN—NOAA/National Climatic Data Center, Asheville, North Carolina; YIN*—STG, Inc., Asheville, North Carolina
CORRESPONDING AUTHOR: Anthony Arguez, NOAA/NCDC, Room 506, 151 Patton Avenue, Asheville, NC 28801
*CURRENT AFFILIATION: ERT, Inc., Asheville, North Carolina
E-mail: anthony.arguez@noaa.gov

The abstract for this article can be found in this issue, following the table of contents.

DOI:10.1175/BAMS-D-11-00197.1
In final form 13 April 2012

https://doi.org/10.1175/BAMS-D-11-00197.1

Assignment

Climate normals from GPCP

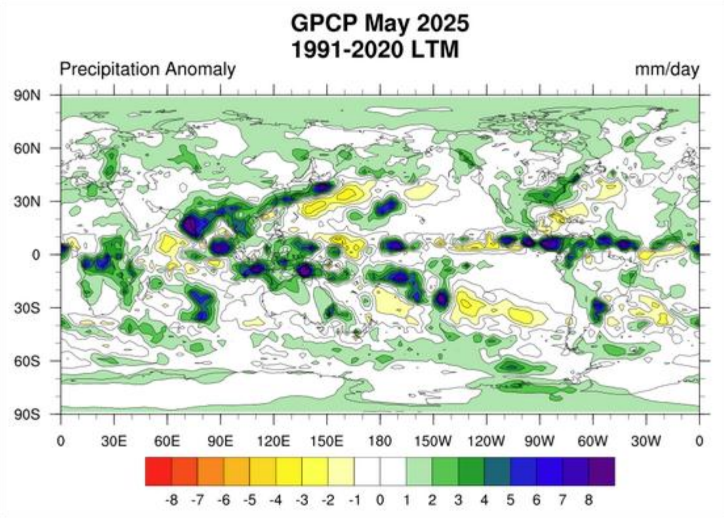
Climate normals from GPCP for EU

1. Get *pr* data from NOAA [1979-2022, monthly mean]
2. Select the base period [e.g. Jan 1979- Dec 2008, 30yr]
3. Compute monthly climatological mean
4. Make a comparison with 2022 data

psl.noaa.gov/data/gridded/data.gpcp.html

Physical Sciences Laboratory

About | People | Research | Data | Products | News | Events | Learn



Download and Plot Data

Data Help

Search Dataset Variables (start with * to match anywhere) | Clear

+ / -

Variable	Statistic	Level	TimeScale	Options
Precipitation				
1 Precipitation	Error	Surface	Monthly	
2 Precipitation	Long Term Mean	Surface	Monthly	
1 Precipitation	Mean	Surface	Monthly	

Thredds Catalog: Download: Plot/Subset:

SPECIFICATIONS

Temporal Coverage

- Monthly values 1979/01 through present
- Long term monthly means, derived from years 1981 to 2010

Spatial Coverage

- 2.5 degree latitude x 2.5 degree longitude global grid (144x72)
- 88.75N - 88.75S, 1.25E - 358.75E

Levels

- Surface

Update Schedule

- Monthly

Dataset Format and Size

- CF metadata standard, NetCDF4 format.

Missing Data

- Missing data is flagged with a value of -9.96921e+36f.

DESCRIPTION +

USAGE & CITATION +

SOURCE & REFERENCES +

VARIABLES +

[redacted]

downloads.psl.noaa.gov/Datasets/gpcp/

An official website of the United States government Here's how you know

Physical Sciences Laboratory

About People Research Data Products News | Events Learn

Index of /Datasets/gpcp

Name	Last modified	Size
Parent Directory		-
gpcp_citation_list.pdf	2016-11-08 14:28	718K
precip.mon.ltm.1981-2010.nc	2021-09-02 10:19	734K
precip.mon.ltm.1991-2020.nc	2022-06-10 09:35	662K
precip.mon.ltm.nc	2022-06-10 09:35	662K
precip.mon.mean.error.nc	2025-06-12 04:01	19M
precip.mon.mean.nc	2025-06-12 04:01	20M

Mailing Address

NOAA PSL
325 Broadway
Boulder, CO 80305-3328

External Links

Links to external, non-government Web sites are annotated with an icon: External links disclaimer

Physical Sciences Laboratory

About
Contact Us
Public Affairs
Site Index
Take Our Survey
Webmaster

More

Privacy Policy
Disclaimer
Accessibility
USA.gov

DOC | NOAA | OAR

https://psl.noaa.gov/data/gridded/data.gpcp.html

How to build a climatology

Mean state. 30-year period (also 50yr)

Select a variable & time period

(e.g., precipitation for the 1981-2010 period)

	Y1	Y2	…	Y30
Jan	P(1,Y1)	P(1,Y2)	…	P(1,Y30)
Feb	P(2,Y1)	P(2,Y2)	…	P(2,Y30)
…	…	…	…	…
Dec	P(12,Y1)	P(12,Y2)	…	P(12,Y30)

P(2) = Mean(All monthly data for 30 year)

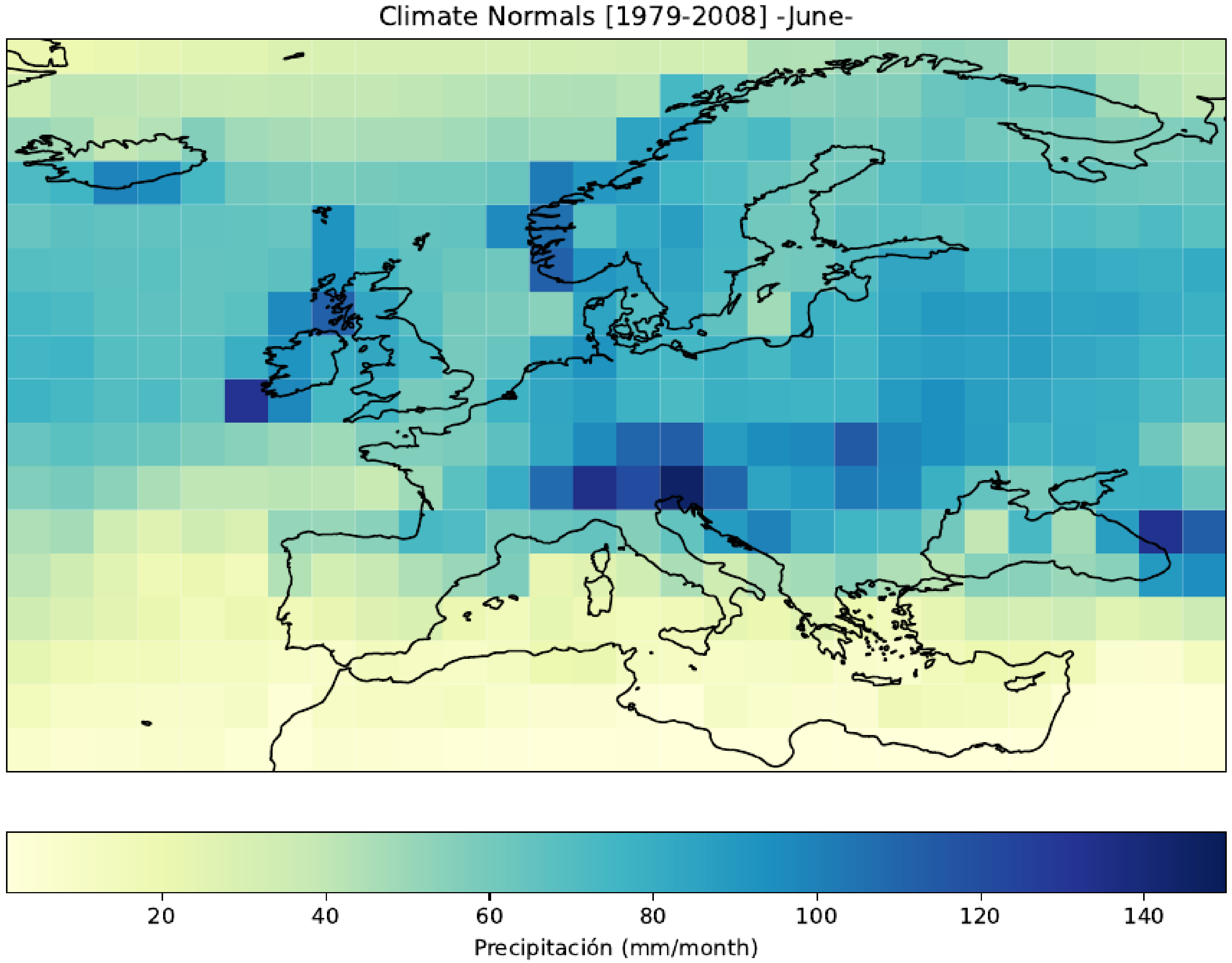
Create monthly climatologies with CDO

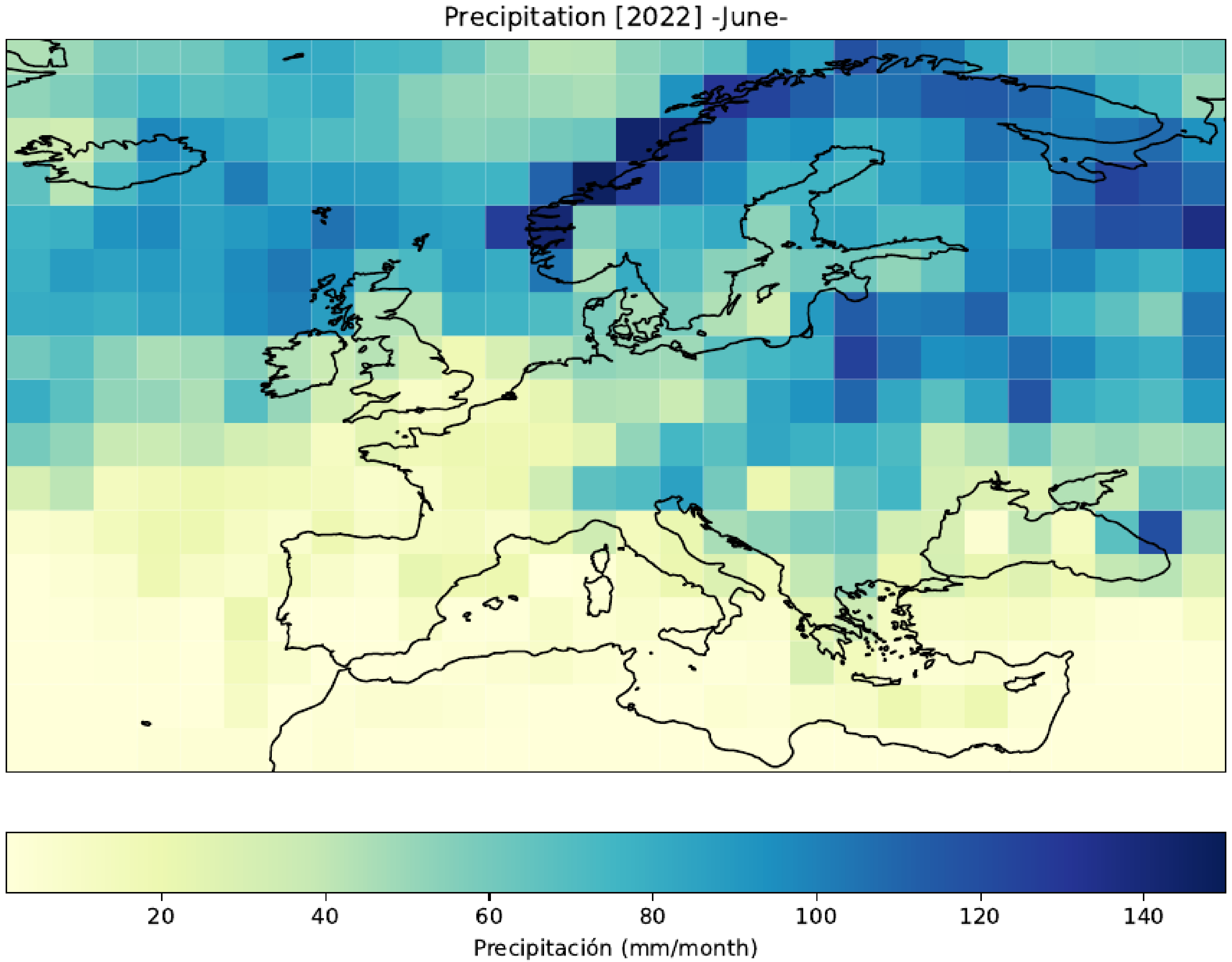
```
cdo seltimestep,1/360 input.nc output.nc
```

Create monthly climatologies with CDO

```
cdo ymonmean input.nc output.nc
```

[redacted]


Climate Normals [1979-2008] -June-
20
40
60
80
100
120
140
Precipitación (mm/month)


Precipitation [2022] -June-
20
40
60
80
100
120
140
Precipitación (mm/month)

Computing climate normals with Python & xarray

```
from matplotlib import pyplot as plt
import numpy as np
import xarray as xr
import cartopy.crs as ccrs
import cartopy.feature as cfeature
import os

wdir="/home/andres/owncloud/docencia/ULE/datos-IA/assignments/PID-CLIMATOLOGIES/data/original"
pr_in=xr.open_dataset(wdir+"/"+"precip.mon.mean.nc") #data is 557x72x144 (time,lat,lon)
pr_in.data_vars       #listar variables
pr_in.dims            #listar dimensiones
pr=pr_in["precip"]      # save the variable

# Time baseline [1979-2008, 30yrs. (360x72x144)]
tstart='1979-01-01'
tend='2008-12-31'
prbaseline= pr.sel(time=slice(tstart, tend))

# Compute climatology (12x72x144)
prmonclim=prbaseline.groupby('time.month').mean('time')
prmonclim=prmonclim*30 # from mm/day to mm/month

# European limits
lon_min, lon_max = -25, 45
lat_min, lat_max = 30, 72

.....
```

```
# First plot
data_clim = prmonclim.sel(month=6) #June
fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={'projection': ccrs.PlateCarree()}) # Crear figura y ejes con proyección geográfica
img = ax.pcolormesh(data_clim.lon, data_clim.lat, data_clim, cmap='YlGnBu', shading='auto', vmin=1.0, vmax=150) # Dibujar el mapa de precipitación
ax.coastlines() # Añadir características geográficas
ax.set_extent([lon_min, lon_max, lat_min, lat_max], crs=ccrs.PlateCarree())
ax.set_title(f'Climate Normals [1979-2008] -June-')
cbar = plt.colorbar(img, ax=ax, orientation='horizontal', pad=0.05) # Añadir barra de color
cbar.set_label('Precipitación (mm/month)')
plt.savefig("EU_climate-normals_june_1979-2008",format="pdf")


# Second plot
data_pr = pr.data[522,:,:]*30 #June in mm/month
fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={'projection': ccrs.PlateCarree()}) # Crear figura y ejes con proyección geográfica
img = ax.pcolormesh(data_clim.lon, data_clim.lat, data_pr, cmap='YlGnBu', shading='auto', vmin=1.0, vmax=150) # Dibujar el mapa de precipitación
ax.coastlines() # Añadir características geográficas
ax.set_extent([lon_min, lon_max, lat_min, lat_max], crs=ccrs.PlateCarree())
ax.set_title(f'Precipitation [2022] -June-')
cbar = plt.colorbar(img, ax=ax, orientation='horizontal', pad=0.05) # Añadir barra de color
cbar.set_label('Precipitación (mm/month)')
plt.savefig("EU_precipitation_june_2022",format="pdf")
```