

Regional Initiative for the Assessment of Climate Change Impacts on Water Resources & Socio-Economic Vulnerability in the Arab Region

RICCAR
Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region

**WEBINAR SERIES ON
CLIMATE CHANGE ANALYSIS USING GIS TOOLS**

Module 2:
Viewing NetCDF regional climate modelling datasets in GIS

UNITED NATIONS
الأمم المتحدة
ESCWA



Webinar Series

- **Module 1:** RICCAR regional climate modelling and hydrological modelling datasets: An introduction
- ✓ **Module 2:** [Viewing NetCDF regional climate modelling datasets in GIS](#)
- **Module 3:** Extracting tabular data from NetCDF climate files for use in other models and applications
- **Module 4:** Creating a regional climate model ensemble using GIS and extreme events indices
- **Module 5:** Accessing global and regional climate datasets and platforms
- **Module 6:** RICCAR integrated vulnerability assessment methodology

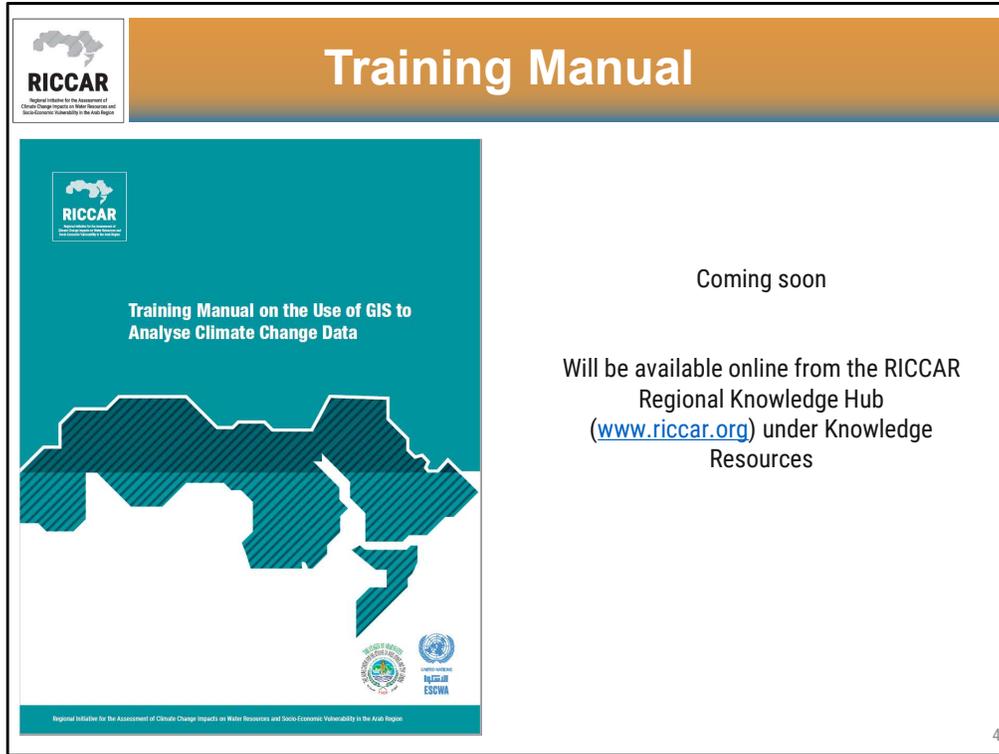
2



Module 2: Contents

- What is NetCDF
- Multidimension tools: Working with NetCDF files in a GIS platform
- Visualizing NetCDF files

3



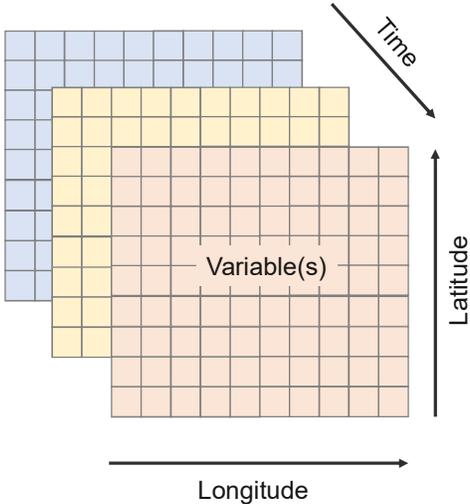
The image shows a slide titled "Training Manual" with an orange header. On the left is a cover for the "Training Manual on the Use of GIS to Analyse Climate Change Data". The cover features a teal background with a stylized map of the Arab region. Logos for RICCAR, UNESCWA, and the United Nations are visible. On the right, text announces the manual's availability: "Coming soon" and "Will be available online from the RICCAR Regional Knowledge Hub (www.riccar.org) under Knowledge Resources". A small number "4" is in the bottom right corner of the slide frame.

- Information included in this module is detailed in this training manual and relevant sections will be referenced.
- Manual is currently being finalized and will be available online. We will let participants know when it becomes available. It will be available in both English and Arabic.



What is NetCDF?

- NetCDF (Network Common Data Form) is used for array-based data
- Typically consists of **one or more variables** (i.e. precipitation, temperature) and **two or more dimensions** (i.e. latitude, longitude, time)



5

- Most climate datasets (including RICCAR) are in NetCDF format (designated with a .nc suffix)
- Used for array-based data – allows for the application of an entire set of values at once
- NetCDF files are used for climate, oceanography, air pollution and other datasets and lessons from this module can be applied to other .nc datasets beyond RICCAR
- RICCAR Training Manual on the Use of GIS to Analyse Climate Change Data Section 3.1

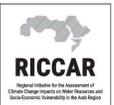


NetCDF Compatible Applications

- **Panoply** – NetCDF viewer developed by NASA Goddard Institute for Space Studies (open access: <https://www.giss.nasa.gov/tools/panoply/download/>)
- **Python** – Can access NetCDF files with the PyNIO module
- **R** – Supports NetCDF through packages such as ncd4 or RNetCDF
- **MatLab** – Can read or write NetCDF files
- **Climate Data Operators (CDO)** – Includes more than 350 operators including calculation of extreme climate indices and statistical analysis (<https://code.mpimet.mpg.de/projects/cdo>)
- **ArcMap GIS**

6

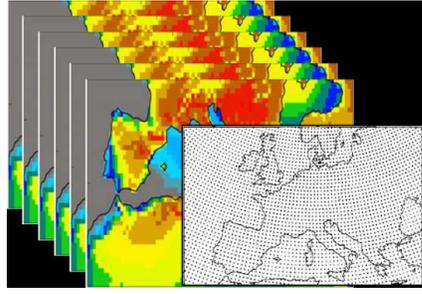
- Listed are a few of the common software platforms that work with NetCDF files



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Advantages of Using ArcMap GIS for NetCDF

- Software familiarity
- Ability to visualize data
- Allows for comparison of other geospatial datasets



7



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Disadvantages of Using ArcMap GIS for NetCDF

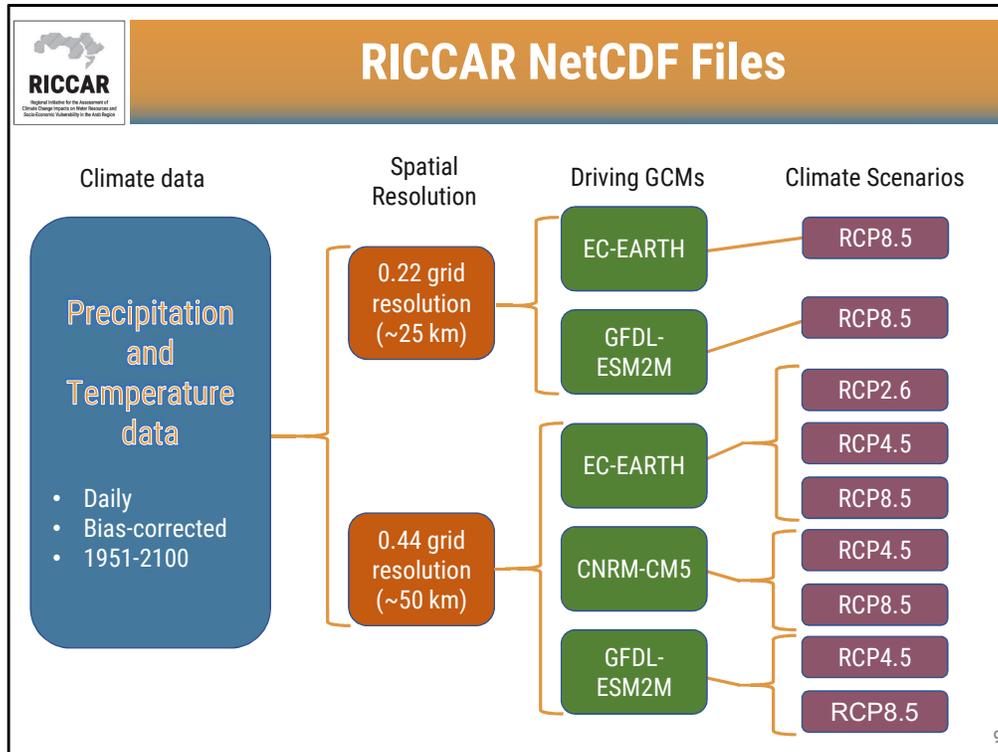
- Limited functions
 - Cannot “clip” data
 - Cannot perform certain analyses

- Not compatible with all NetCDF files
 - Must be netcdf 4 format
 - Must have geospatial data included



8

- Cannot “clip” or extract data based on a shapefile such as country
- Cannot perform analyses such as calculation of extreme climate indices



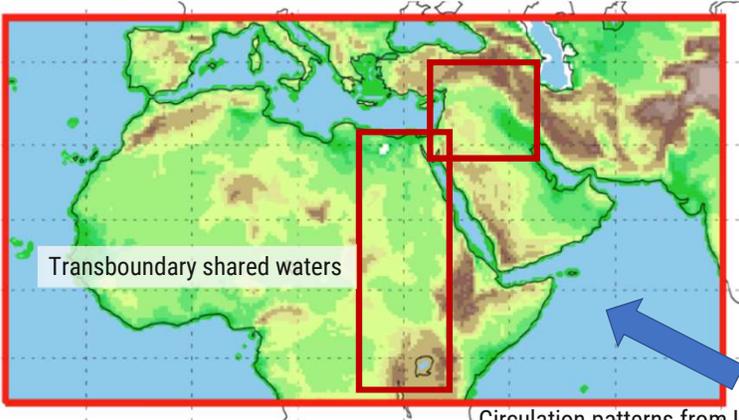
- RICCAR NetCDF data contain the outputs from the Regional Climate Modelling (RCM)
- RCMs are downscaled from three different Global Climate Models (GCM)
- It is recommended to present data as an ensemble mean – meaning over a 20-year period, using outputs based on the 3 driving GCMs (thus limiting data availability to the 0.44 grid/50 km)
- Other datasets (25 km grid, RCP2.6) are available as shown for comparative analysis- but should not be presented as an ensemble mean



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Advantages Using RICCAR RCM Outputs

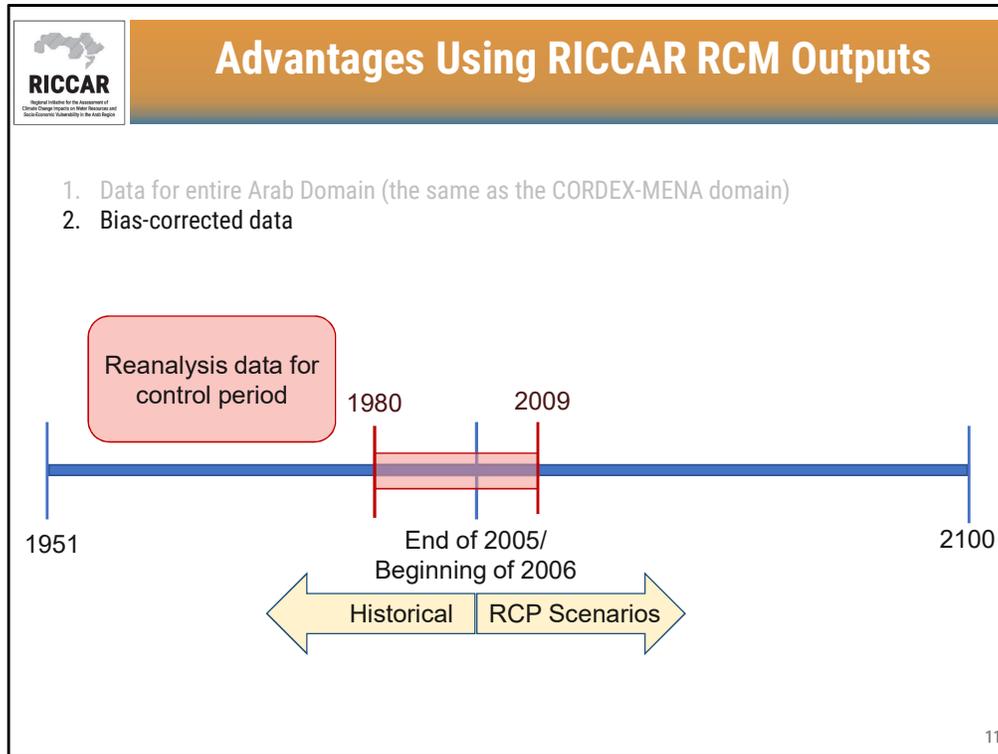
1. Data for entire Arab Domain (the same as the CORDEX-MENA domain)



Same assumptions from east-west, north-south across Arab region

10

- The Coordinated Regional Climate Downscaling Experiment (CORDEX) is a unified framework to conduct regional climate modelling for differing domains around the world. The Arab Domain was established as part of CORDEX (described as Middle East-North Africa)
- RCM outputs for the Arab/Middle East-North Africa domain are available from CORDEX (as well as other domains) but are not bias-corrected data
- More information on CORDEX datasets, how to access, and reasons to access will be covered in webinar module 5



- GCM and RCM modelling outputs have systemic biases which result in some inaccuracies in results, such as unexpected colder temperatures or heavier precipitation. Bias-correction attempts to reduce these inaccuracies by incorporating reanalysis data based on historical meteorological observations
- Note that although bias-correction is widely used, it is still controversial and has some limitations. This is why raw (not-bias-corrected) RCM outputs are still available directly from CORDEX.
- Bias-corrected data is recommended for use in hydrological applications and impact studies which is why used for RICCAR data.
- CORDEX data describes historical data as those modelling outputs through the end of 2005. The RCP scenarios (RCP4.5, RCP8.5) start at the beginning of 2006.
- The reanalysis data (based on observed data) used for the bias-correction included a control period from 1980-2009
- Because of the bias-correction, the “historical” outputs (2005 and before) will very slightly differ based on the RCP scenario. Thus is it important to compare “projected” RCP4.5 outputs to “historical” RCP4.5 outputs; similarly for RCP8.5 “historical” vs “projected”.



Advantages Using RICCAR RCM Outputs

1. Data for entire Arab Domain (the same as the CORDEX-MENA domain)
2. Bias-corrected data
3. Gregorian calendar format

No.	1	2	3	4	5	6	7	8	9	10	11	12
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of days	31	28 (29)	31	30	31	30	31	31	30	31	30	31

Different research agencies may have output using non-conventional calendars

➔

GCM	Calendar
CNRM-CM5	Gregorian
EC-EARTH	Gregorian
GFDL-ESM2M	365-day
CSIRO-Mk3-6-0	365-day
HadGEM2-ES	360-day

- RICCAR RCM outputs use a Gregorian calendar format which is the current international standard based on 365 days per year with 366 days every four years (leap year)
- Other climate modelling outputs may have differing calendars. Note that GFDL-ESM2M outputs on CORDEX are based on a 365-day calendar (including leap year) but the outputs available from RICCAR have been corrected to the Gregorian calendar format. HadGEM2-ES models use a 360-day calendar such that every month (including February) has 30 days.



Advantages Using RICCAR RCM Outputs

1. Data for entire Arab Domain (the same as the CORDEX-MENA domain)
2. Bias-corrected data
3. Gregorian calendar format
4. Extreme climate indices

Index	Long Name	Definition
SU	Number of summer days	Number of days (annually or seasonally) when daily maximum temperature $\geq 25^{\circ}\text{C}$
SU35	Number of hot days	Number of days (annually or seasonally) when daily maximum temperature $\geq 35^{\circ}\text{C}$
SU40	Number of very hot days	Number of days (annually or seasonally) when daily maximum temperature $\geq 40^{\circ}\text{C}$
TR	Number of tropical nights	Number of days (annually or seasonally) when daily minimum temperature $\geq 20^{\circ}\text{C}$

13

- Extreme climate indices are not readily available from CORDEX or other climate modelling output datasets and need to be calculated using CDO (climate data operators) or other software platforms



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Advantages Using RICCAR RCM Outputs

1. Data for entire Arab Domain (the same as the CORDEX-MENA domain)
2. Bias-corrected data
3. Gregorian calendar format
4. Extreme climate indices

Index	Long Name	Definition
CDD	Maximum length of dry spell	Maximum number of consecutive days when daily precipitation < 1 mm
CWD	Maximum length of wet spell	Maximum number of consecutive days when daily precipitation ≥ 1 mm
R10	Number of 10 mm precipitation days	Number of days when daily precipitation ≥ 10mm
R20	Number of 20 mm precipitation days	Number of days when daily precipitation ≥ 20mm
SDII	Simple precipitation intensity index	Ratio of total precipitation (annually or seasonally) the number of wet days

14



Advantages Using RICCAR RCM Outputs

1. Data for entire Arab Domain (the same as the CORDEX-MENA domain)
2. Bias-corrected data
3. Gregorian calendar format
4. Extreme climate indices
5. Common units of measurement

Parameter	Units
Temperature	°C
Precipitation	mm day ⁻¹
Extreme indices (except SDII)	days year ⁻¹ (or days season ⁻¹)
SDII	mm

Climate model standard units

Parameter	Units
Temperature	K
Precipitation	kg m ⁻² s ⁻¹

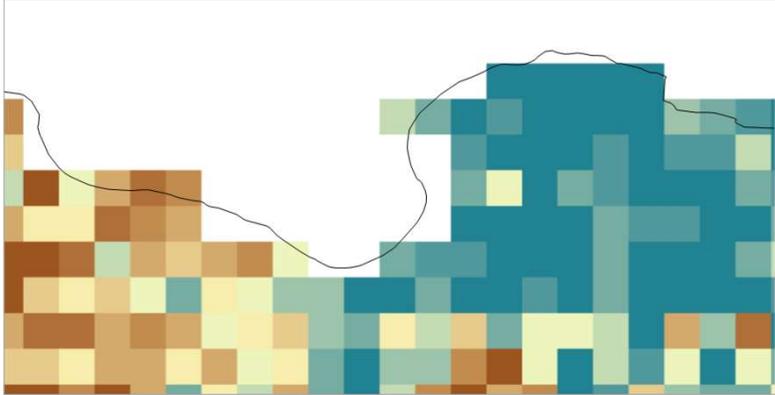
- CORDEX and other climate modelling outputs use units of measurements such as K for temperature and kg/m²/s for precipitation. However, RICCAR RCM outputs use more commonly used units of measurement



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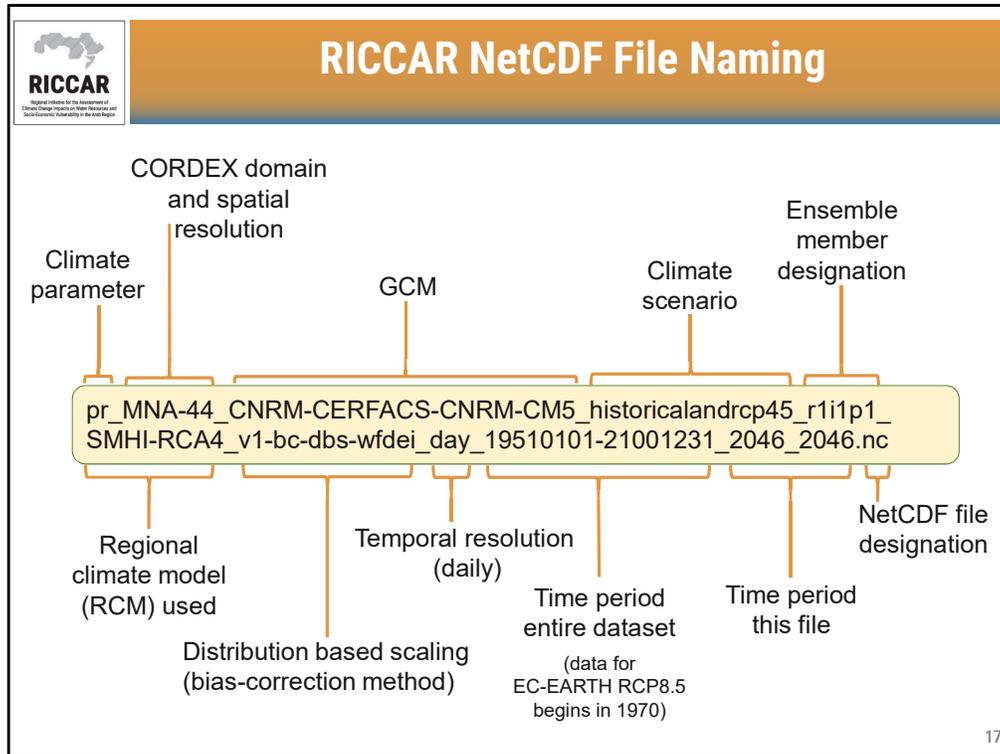
Disadvantages Using RICCAR RCM Outputs

1. Spatial and temporal resolution may be too coarse
2. Some common climate parameters not evaluated (i.e. humidity, wind speed)
3. Data gaps near coastal areas (due to bias-correction)

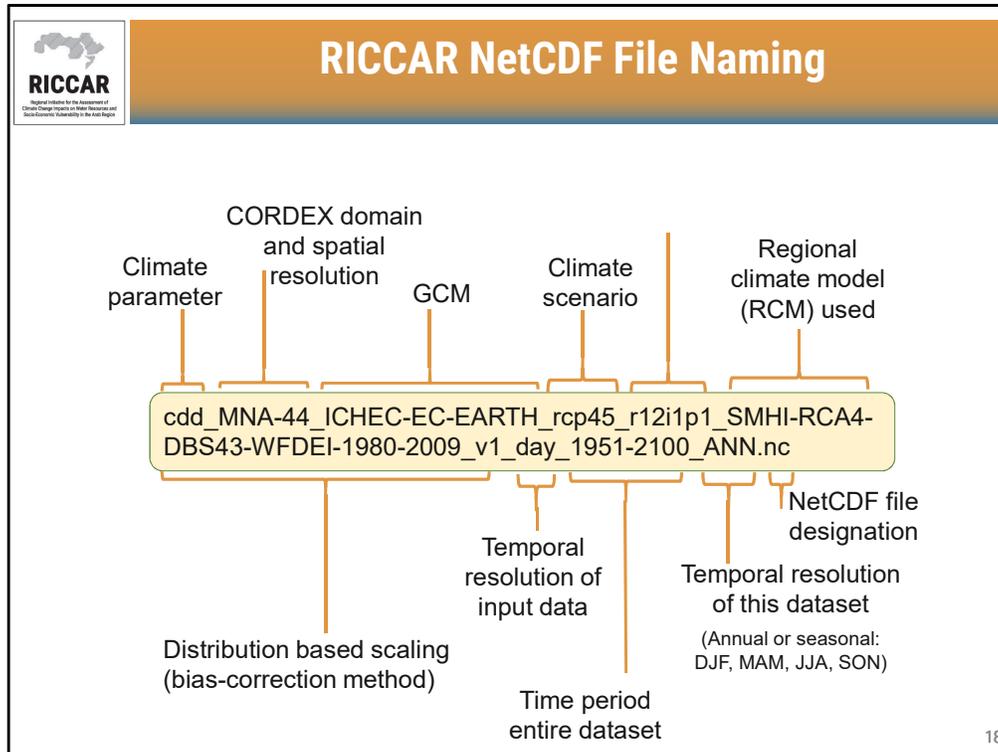


16

- RICCAR modelling outputs were based on a regional analysis. Certain requirements may need finer spatial (less than 25 or 50 km) or temporal (less than 1 day) resolution, such as basin analysis
- Differing modelling output requirements may be met using CORDEX data



- Note that RICCAR datasets follow a similar naming convention as CORDEX
- This is for a sample precipitation NetCDF file. It will be similar for temperature data
- Note that although EC-EARTH data for RCP8.5 begins in 1970, the file name will still show 19510101-21001231 to designate the time period, like the remaining RICCAR NetCDF files



- This naming convention is for the extreme climate indices
- Extreme climate indicators have annual data (designated as ANN) or seasonal data based on 3-month seasons (DJF: December, January, February; MAM: March, April, May; JJA: June, July, August; SON; September, October, November)

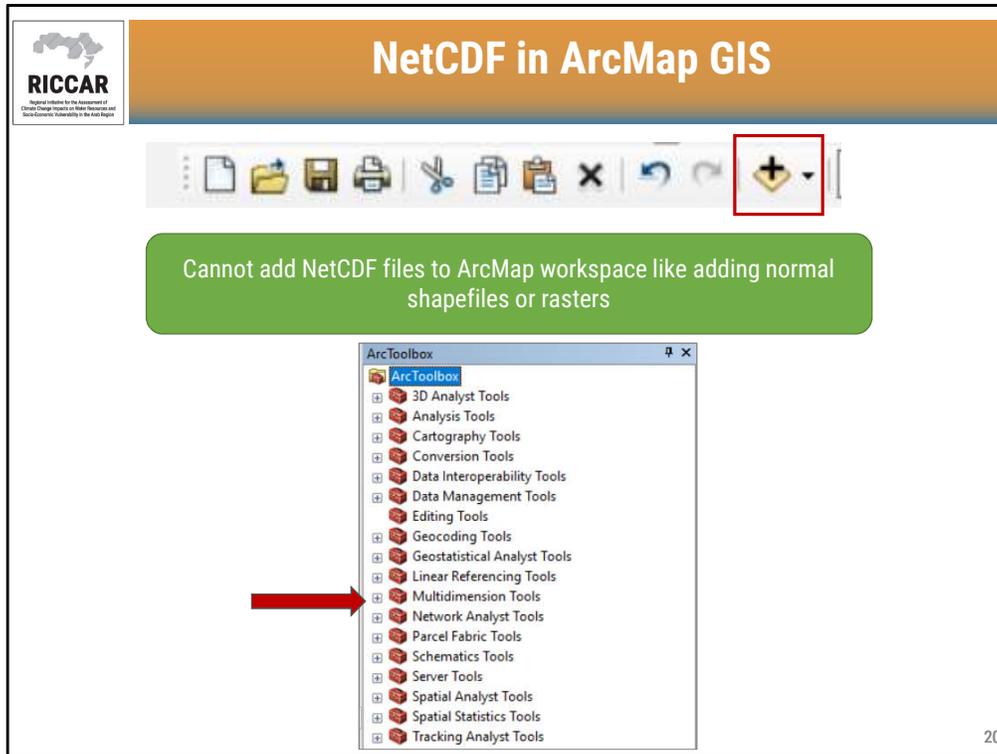


NetCDF File Climate Parameter Abbreviations

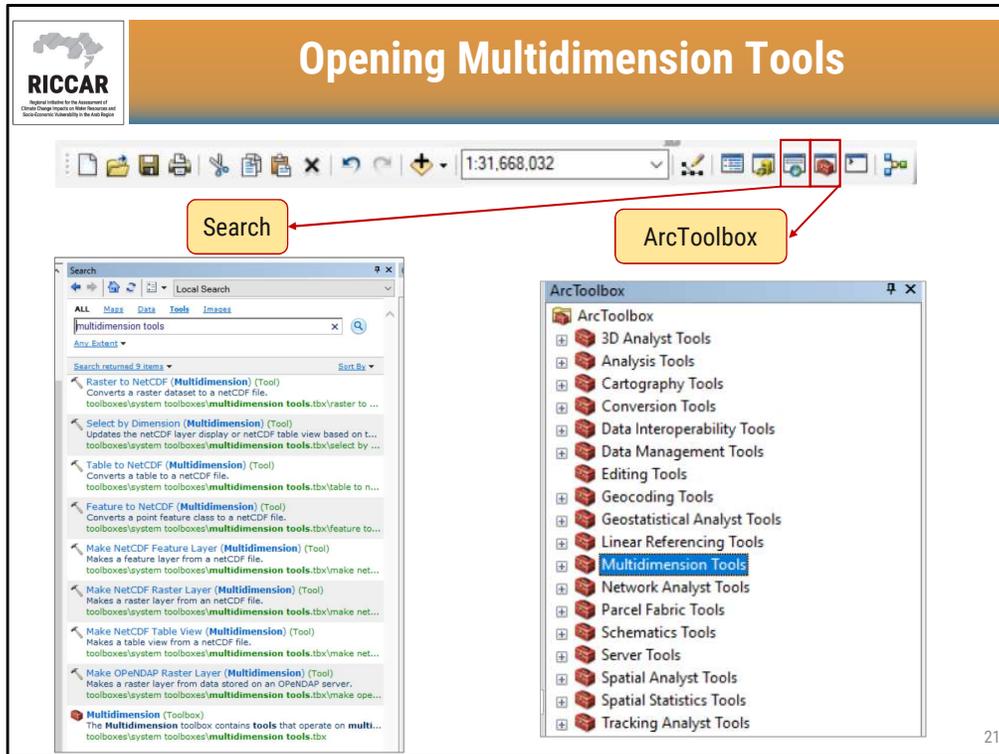
Climate parameter	Abbreviation in NetCDF File
Near-surface air temperature	tas
Daily maximum near-surface air temperature	tasmax
Daily minimum near-surface air temperature	tasmin
Precipitation	pr
Maximum length of dry spell	cdd
Maximum length of wet spell	cwd
Count of 10 mm precipitation days	pr10
Count of 20 mm precipitation days	pr20
Simple precipitation intensity index	sdi
Number of summer days	su
Number of hot days	su35
Number of very hot days	su40
Number of tropical nights	tr

19

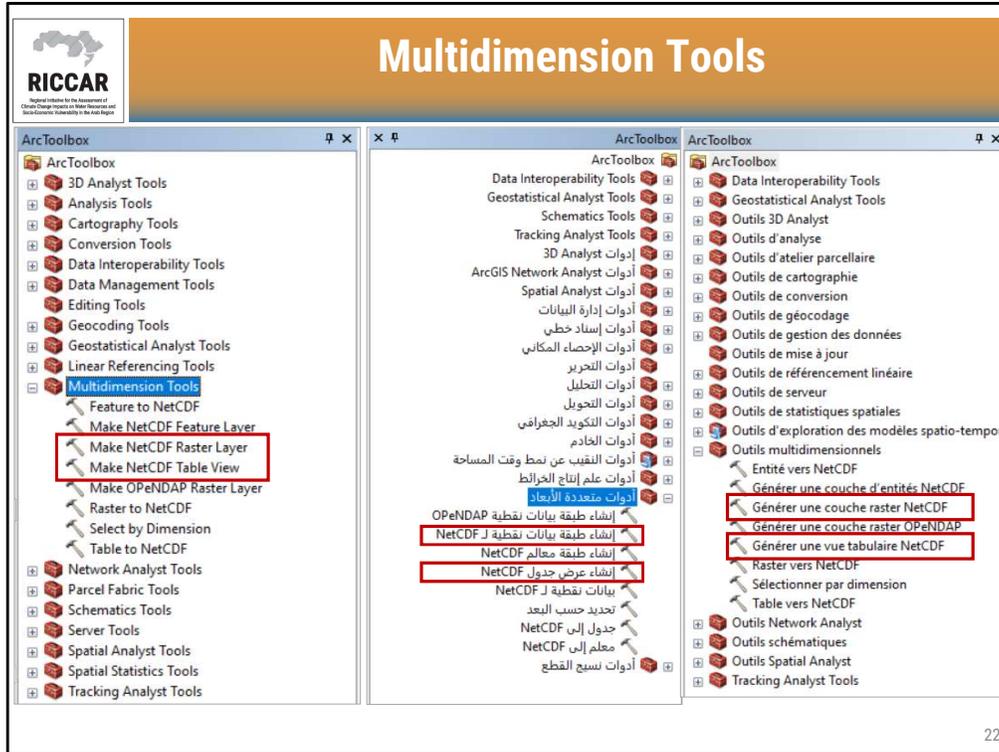
- These abbreviations may differ from the index. (For example, pr10 in file name is for the R10 index).



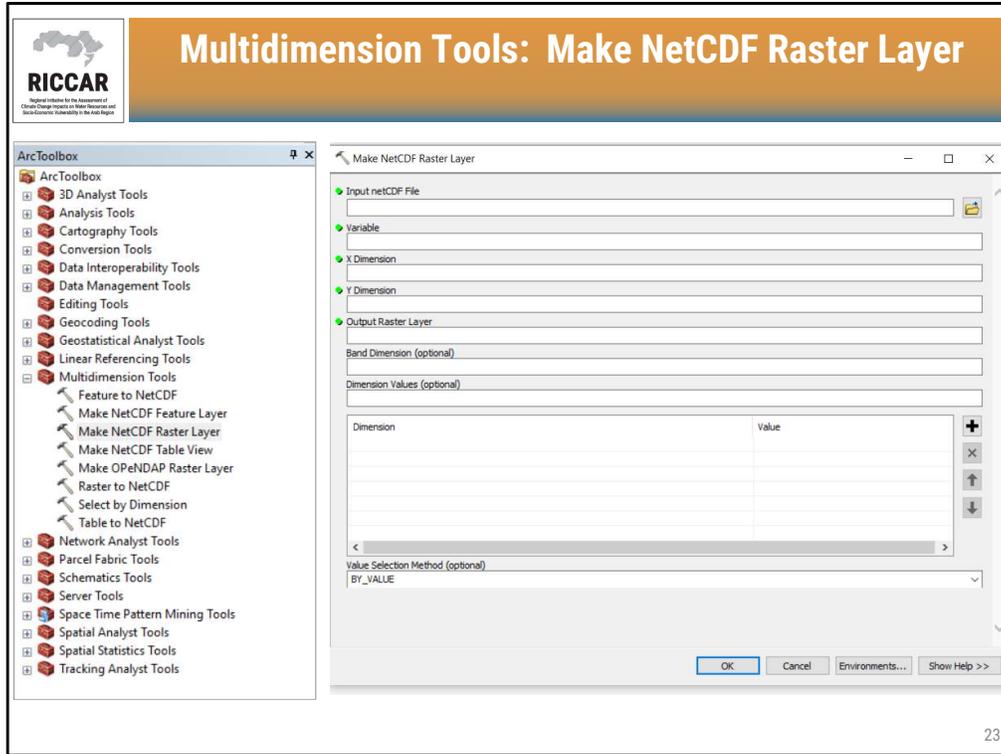
- Normally add data (shapefiles and rasters) to ArcMap workspace using “+” icon. (If this toolbar is not shown, it can be added to GIS by selecting “Customize” and then “Toolbars”. There is an option to select differing toolbars including this one, which is the “standard” toolbar.)
- However, cannot add NetCDF files to ArcMap GIS using the “+” icon. They must be added using the “Multidimension Tools” available from the ArcToolbox
- Note that this webinar series will use an English version of ArcMap GIS. There will be occasional references to the Arabic and French versions to help locate tools.



- Opening the “Multidimension Tools” can be done using the “Search” tool or from the “ArcToolbox” depending on personal preference.



- Multidimension tools have multiple functions. The 2 most commonly used (covered in this webinar series) are shown.
- Available from ArcMap version 10.2 or later.

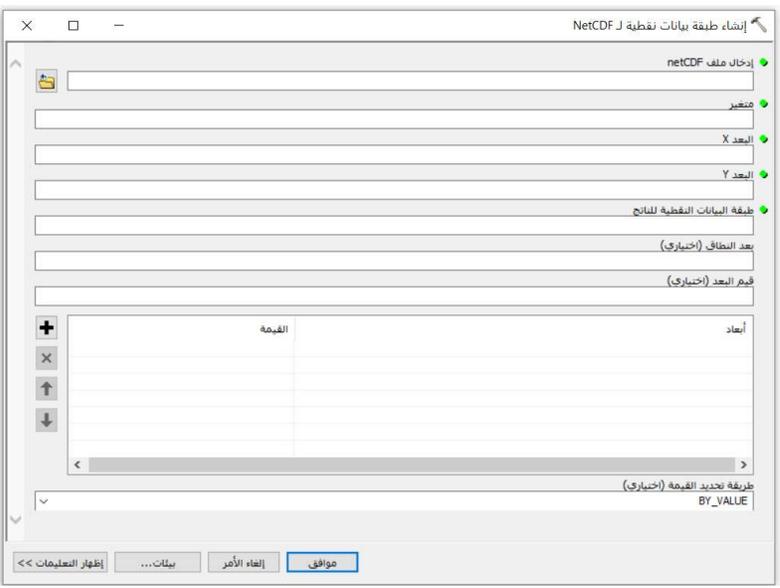


- RICCAR Training Manual on the Use of GIS to Analyse Climate Change Data Section 3.2.



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Multidimension Tools: Make NetCDF Raster Layer (Tool in Arabic)



إنشاء طبقة بيانات نقطية لـ NetCDF

إدخال ملف netCDF

متغير

البعد X

البعد Y

طبقة البيانات النقطية للنتائج

بعد النطاق (اختياري)

قيم البعد (اختياري)

القيمة	أبعاد

طريقة تحديد القيمة (اختياري) BY_VALUE

إظهار التعليمات << بيانات... إنهاء الأمر موافق

24



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Multidimension Tools: Make NetCDF Raster Layer (Tool in French)

Générer une couche raster NetCDF

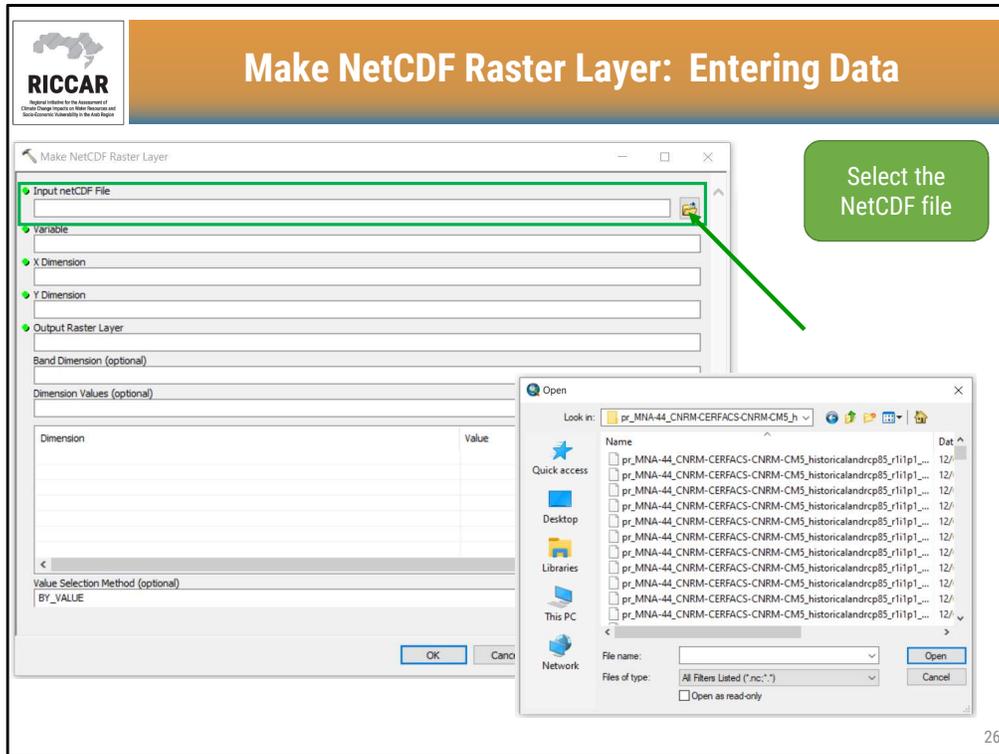
- Fichier NetCDF en entrée
- Variable
- Dimension X
- Dimension Y
- Couche raster en sortie
- Dimension de canal (facultatif)
- Valeurs de dimension (facultatif)

Dimension	Valeur

Méthode de sélection de valeurs (facultatif)
BY_VALUE

OK Annuler Environnements Afficher l'aide >>

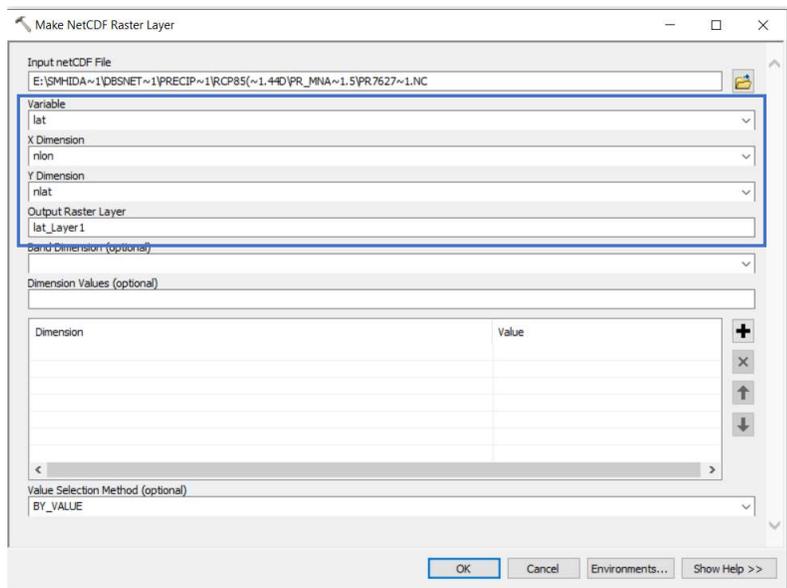
25



- Select the NetCDF file by clicking on the folder icon and picking the folder where you have saved NetCDF files to your computer.

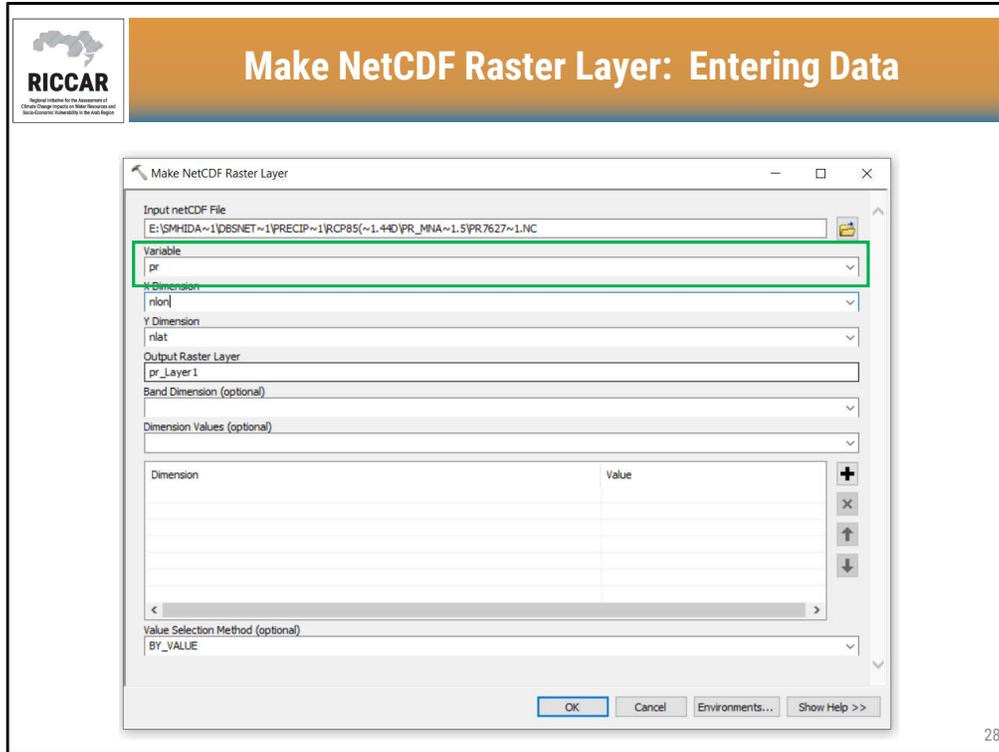


Make NetCDF Raster Layer: Entering Data

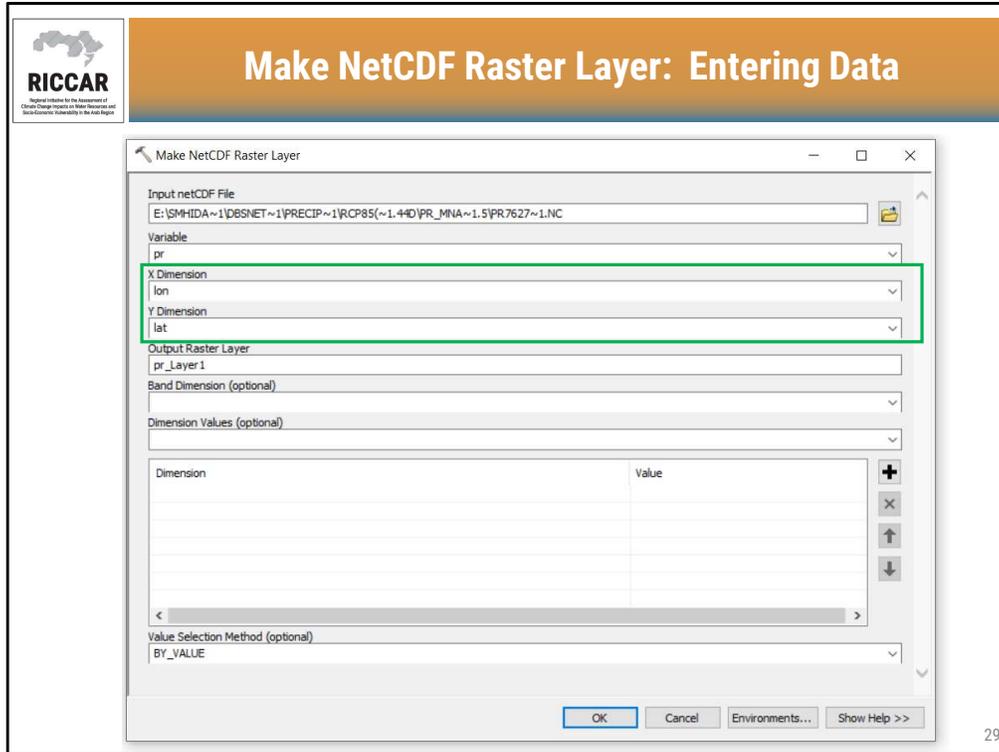


Default entries
(must be manually changed)

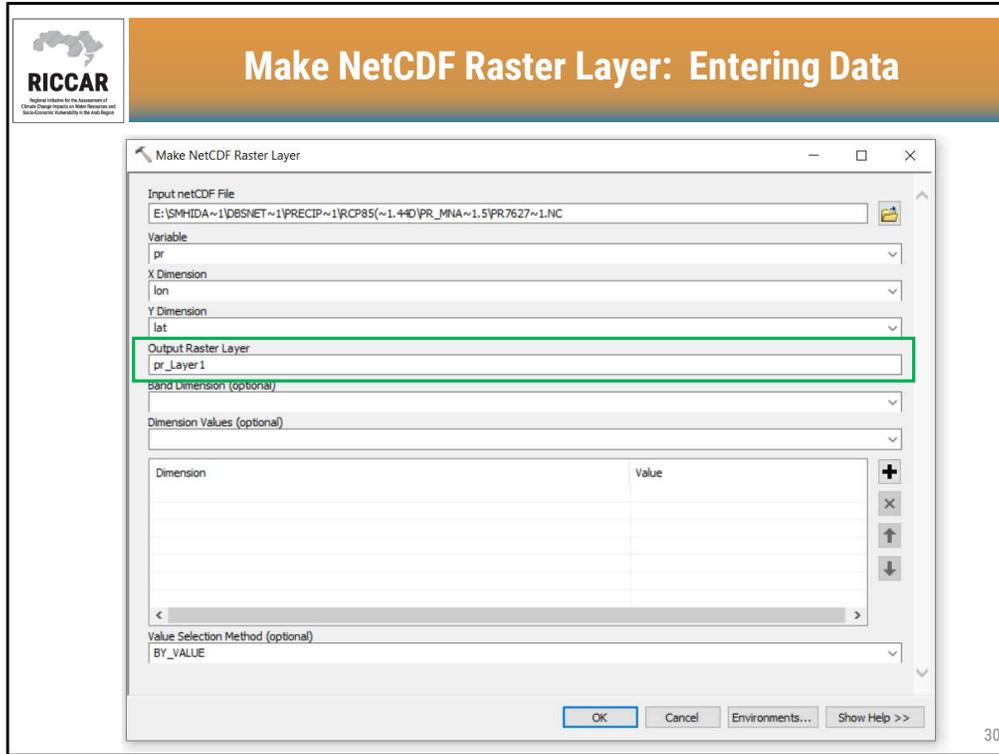
27



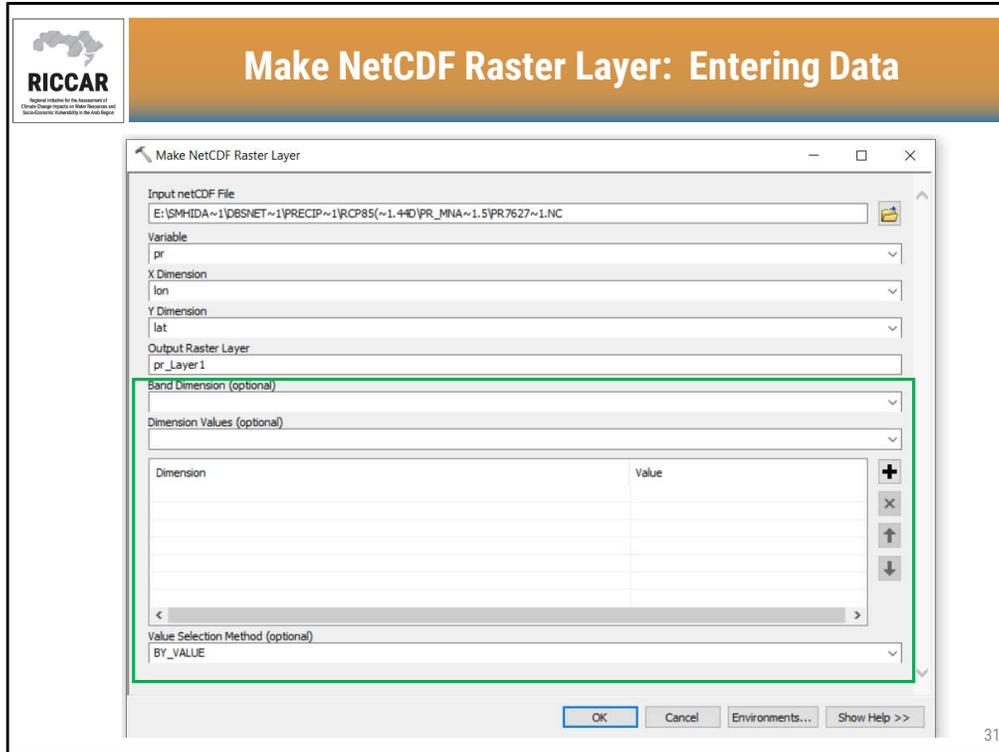
- For “Variable”, pick the climate parameter abbreviation. In this example, “pr” is selected for precipitation. All climate parameter abbreviations for RICCAR data is on slide 19 of this module.



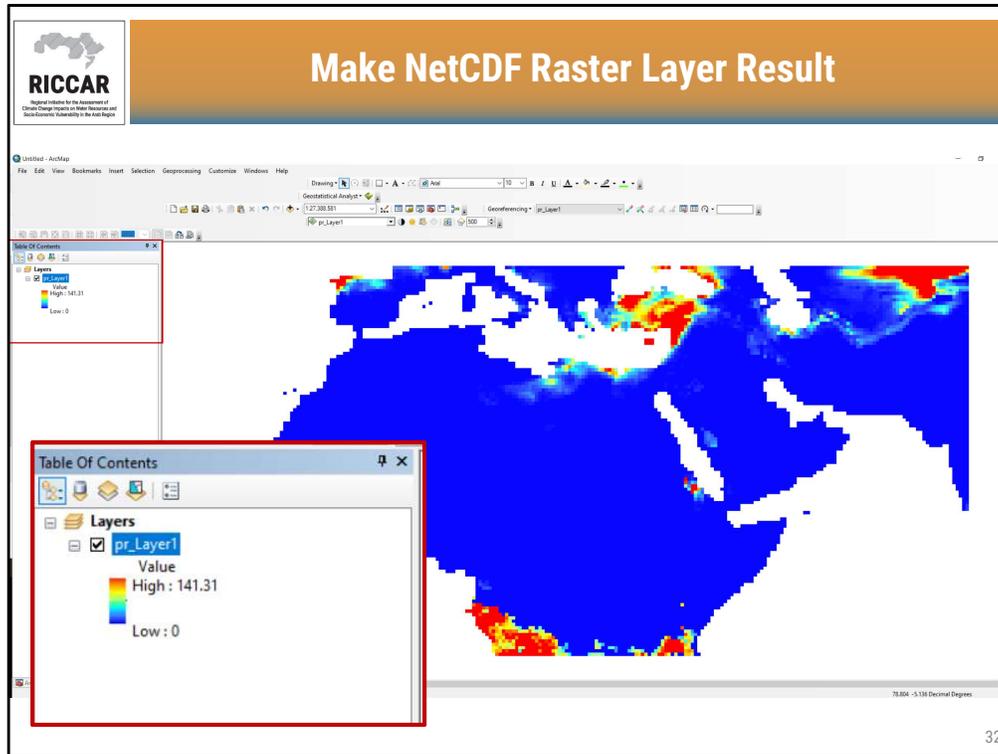
- For the “X Dimension” and “Y Dimension”, select “lon” (for longitude) and “lat” (for latitude), respectively.
- The nlon and nlat dimensions will be discussed in Webinar Module 3.
- If default nlon and nlat are used, the resultant raster layer will be georeferenced incorrectly and not match up with shapefiles and other GIS datasets.



- For the “Output Raster Layer”, the default name can be left as is or user defined.



- Remaining entries are optional and not used for RICCAR data as well as most climate datasets.
- Once all entries are complete, click “OK”.



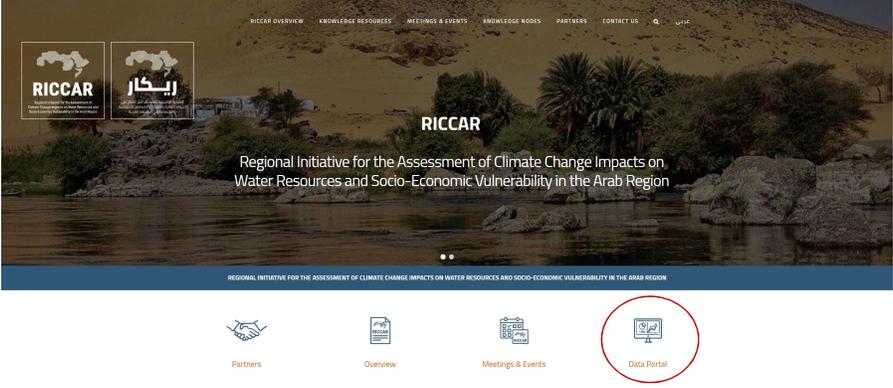
- Result will be a raster layer as shown
- Note that color scheme is automatically determined by ArcMap and may be different for other language versions.



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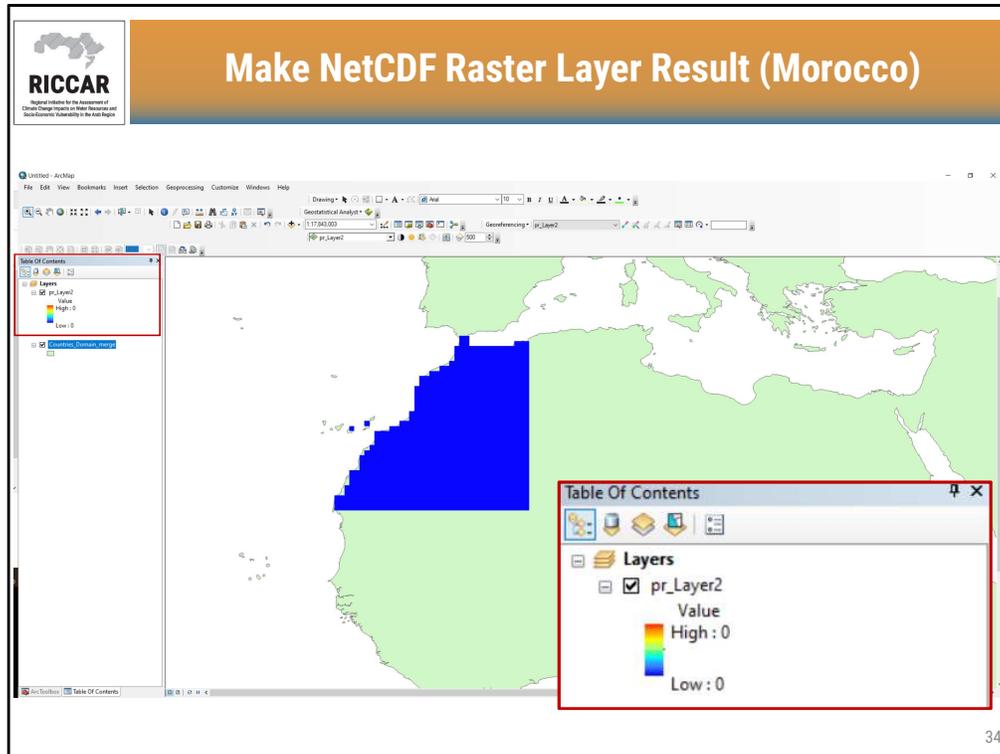
Notes on NetCDF Files

- NetCDF file provided to participants and available on Webinar series event website is an extracted file based on Morocco (to reduce file size)
- Complete NetCDF files are available from the RICCAR Regional Knowledge Hub data portal (www.riccar.org) or upon request



33

- The NetCDF file for Morocco is obtained from RICCAR NetCDF file and was extracted using CDO (Climate Data Operators).
- More information about the RICCAR Regional Knowledge Hub (RKH) data portal will be discussed in Module 5.



- Arab Domain shapefile is included in background to give spatial reference.



Notes on NetCDF Raster Layers

- Each NetCDF file contains multiple “time slices”
 - Temperature and precipitation files have 365 time slices (one for each day of the year) except for leap years which have 366 time slices
 - Extreme climate indices have 150 time slices (one for each year 1951-2100)
- By default, the first time slice is shown in the raster layer
 - January 1 for temperature and precipitation data
 - 1951 for extreme climate indices

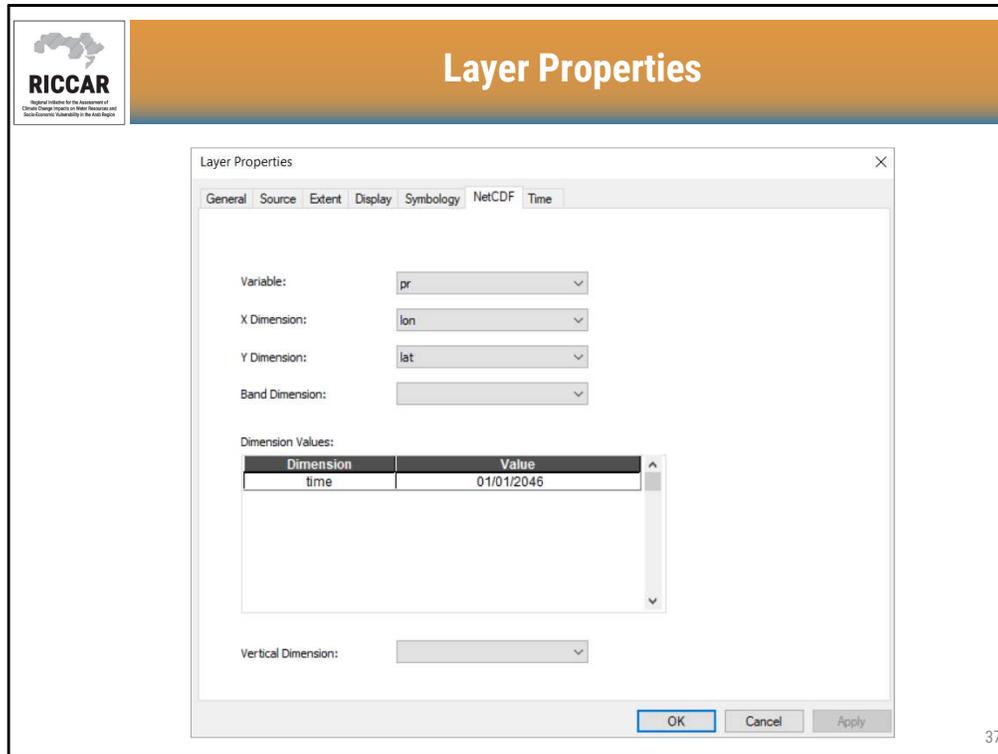
35

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Select Other "Time Slices"

Right click on layer name
in Table of Contents to
display layer properties

36



- Multiple tabs are available under Layer Properties. The NetCDF properties are found in the “NetCDF” tab, including the current raster layer time slice (i.e. date, year).



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Layer Properties (in Arabic)

خصائص الطبقة

عامالمصدرنطاقعرضالرمزيةNetCDFالوقت

▼prمسنوع:

▼lonالبعد X:

▼latالبعد Y:

▼نطاق البعد:

▼قيم البعد:

القيمة	البعد
01/01/2046	time

▼أبعاد رأسية:

OK Cancel Apply



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Layer Properties (in French)

Propriétés de la couche ✕

Général
Source
Etendue
Affichage
Symbologie
NetCDF
Temps

Variable:

Dimension X:

Dimension Y:

Dimension de canal:

Valeurs de dimension:

Dimension	Valeur
time	01/01/2046

Dimension verticale:

39

Layer Properties: Select Time Slice

Variable: pr

X Dimension: lon

Y Dimension: lat

Band Dimension:

Dimension Values:

Dimension	Value
time	01/01/2046
	01/01/2046 00:00:00
	01/02/2046 00:00:00
	01/03/2046 00:00:00
	01/04/2046 00:00:00
	01/05/2046 00:00:00
	01/06/2046 00:00:00

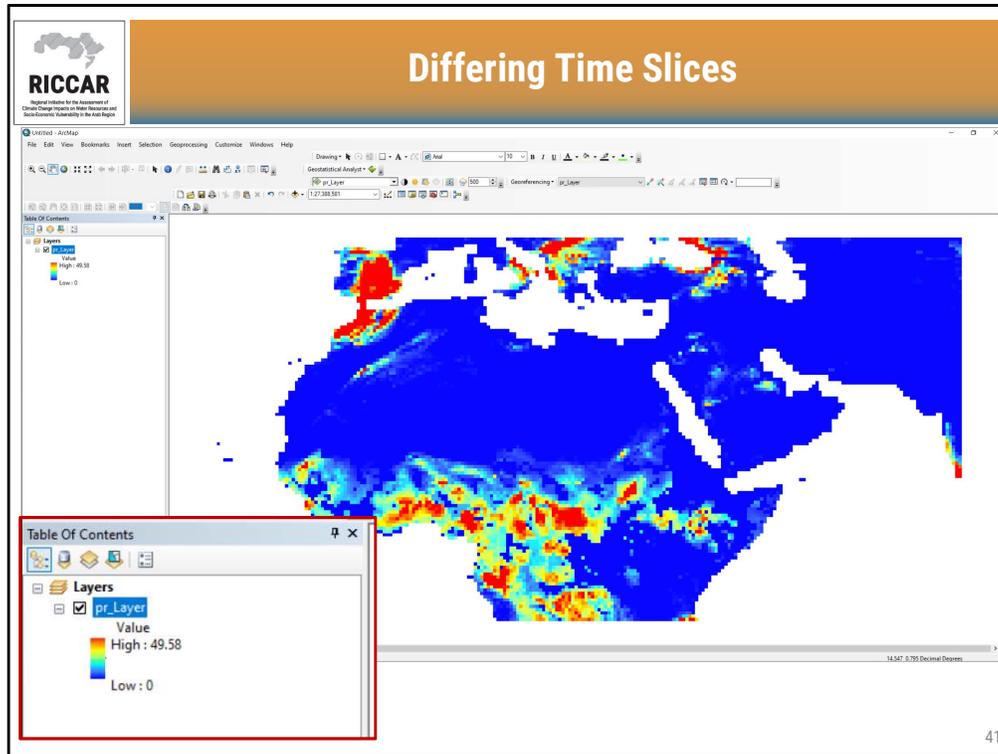
Vertical Dimension:

OK Cancel Apply

Select different dates using the dropdown box

40

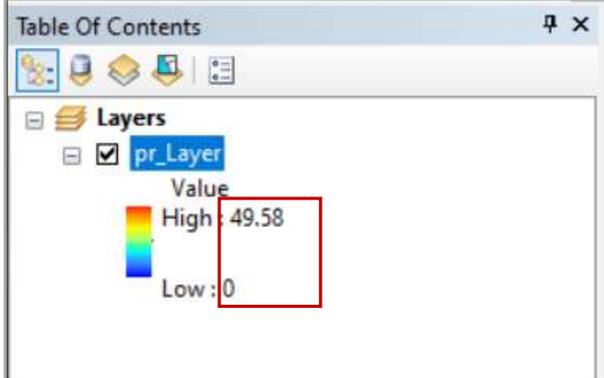
- Note that ArcMap may have differing ways the time slices are shown. Users may have month-day-year and time like shown. The time is shown but is not applicable in this case because there is only value per day.
- Some users may have day-month-year and no time shown. Also, other users may not have the ability to use the dropdown box and may have to enter differing dates manually. This may require trial to determine whether dates are entered as month-day-year or day-month-year.



- By selecting differing time slices, the raster shown and the values will adjust accordingly. This example is 10 June 2046.



Range of Values



The highest values for this time slice (10 June 2046) are 49.58 mm/day of precipitation and displayed in red

42

- Users must consider the temporal resolution of the NetCDF file. Because RICCAR precipitation NetCDF files are daily, the units of measurement are mm/day.



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Saving Raster Layer

- NetCDF raster layers are only in the computer temporary memory
- Raster layers can be saved by selecting “Save as Layer File” or by exporting data

Layers

- Copy
- Remove
- Open Attribute Table
- Joins and Relates
- Zoom To Layer
- Zoom To Make Visible
- Zoom To Raster Resolution
- Visible Scale Range
- Data
- Edit Features
- Save As Layer File...
- Create
- Property

Save As Layer File

Save this layer as a file (saves the layer definition not the data)

Table Of Contents

- Copy
- Remove
- Open Attribute Table
- Joins and Relates
- Zoom To Layer
- Zoom To Make Visible
- Zoom To Raster Resolution
- Visible Scale Range
- Data
- Edit Features
- Save As Layer File...
- Create Layer Package...
- Properties...

Data

- Repair Data Source...
- Export Data...
- Add to Mosaic Datasets
- Make Permanent...
- View Item Description...

Export Data

Export raster data from this layer to the format of your choice. You can also choose other settings, such as the extent of data, the spatial reference, and cell size.



43

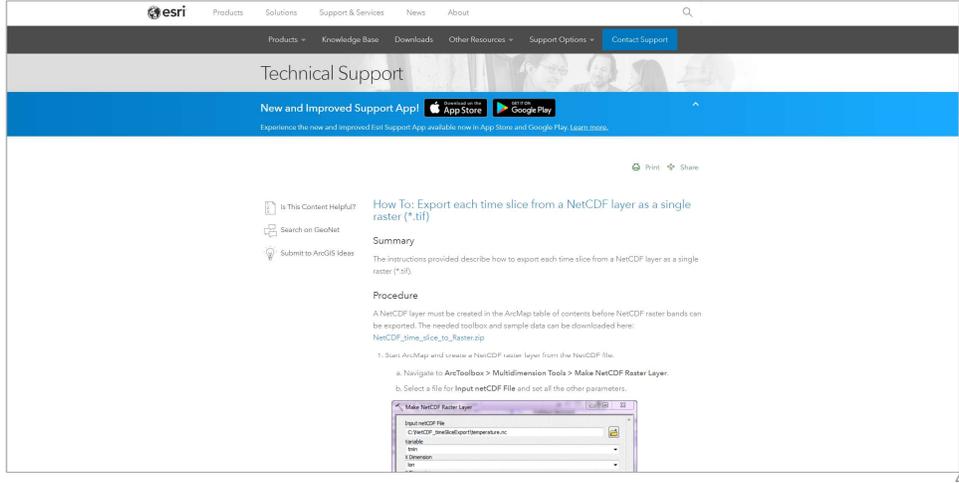
- Exporting data will only export the currently displayed raster time slice.



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Extract Multiple Time Slices

- Users can automatically extract every time slice in the NetCDF file
- Instructions and tool download is available from the following website:
<https://support.esri.com/en/technical-article/000011318>



The screenshot shows the Esri Technical Support page for the article "How To: Export each time slice from a NetCDF layer as a single raster (*.tif)". The page includes a navigation menu, a search bar, and a sidebar with options like "Is This Content Helpful?", "Search on GeoNet", and "Submit to ArcGIS Ideas". The main content area contains a "Summary" section stating that the instructions describe how to export each time slice from a NetCDF layer as a single raster (*.tif), and a "Procedure" section with steps: 1. Start ArcMap and create a NetCDF raster layer from the NetCDF file; 2. Navigate to ArcToolbox > Multidimension Tools > Make NetCDF Raster Layer; 3. Select a file for Input netCDF File and set all the other parameters. A small screenshot of the "Make NetCDF Raster Layer" dialog box is also visible, showing the "Input NetCDF File" field set to "C:\netcdf_data\export\temperature.nc".

RICCAR Training Manual on the Use of GIS to Analyse Climate Change Data Section 3.2.2.



Extract Multiple Rasters based on Subareas of Interest

- Can use ArcMap Model Builder to automatically extract multiple rasters for a specified area (shapefile)
- Discussed in RICCAR Training Manual on the Use of GIS to Analyse Climate Change Data Section 3.2.3.

45

- Model Builder will be discussed in Module 3.

Thank You

RICCAR
Regional Institute for the Assessment of
Climate Change Impacts on Water Resources and
Socio-Economic Vulnerability in the Arab Region

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الموارد المائية والقطاعات الاقتصادية
والاجتماعية في المنطقة العربية

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