Moving from regional climate modelling to vulnerability assessment

Ihab Jnad

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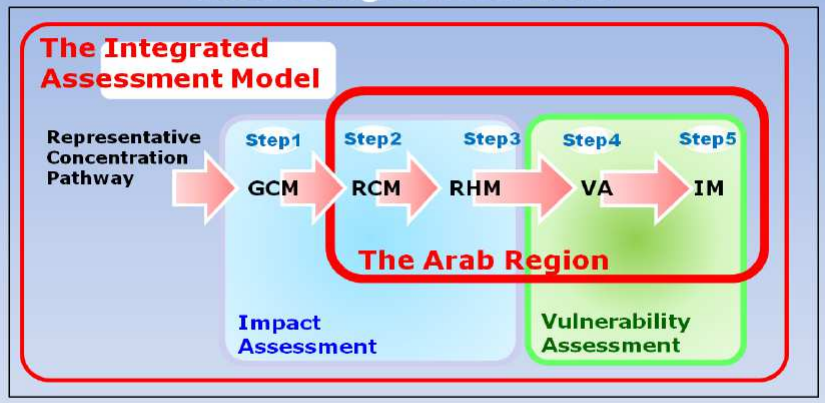
The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD)

Climate Change Integrated Assessment Methodological Framework

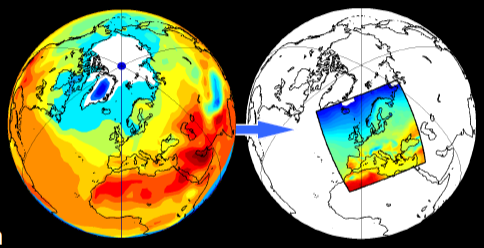


Step 1: Global Climate Modeling using General Circulation Model
Step 2: Regional Climate Modeling
Step 3: Regional Hydrological Modeling
Step 4: Vulnerability Assessment
Step 5: Integrated Mapping

Regional Climate Modelling

Global coverage (GCM)

200-300 km resolution



Regional "Domain" (RCM)

10-50 km resolution

Regional Climate Models (RCMs) are used to investigate a specific region of the globe in more detail

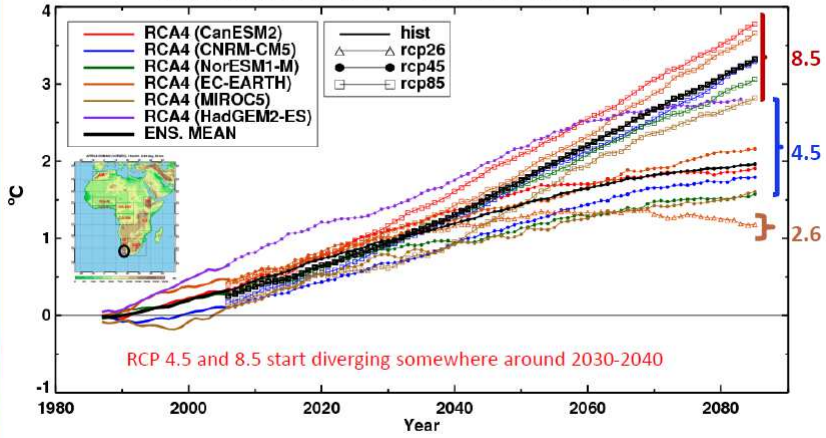
SMHI

SMHI

Newest Climate scenarios using RCPs

An example from the CORDEX Africa domain

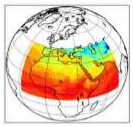
2m Temperature anomalies wrt 1970-2000 | 31-yr. mov. mean | (tas) | ANN | South Africa, West South (SA-WS) 14E-20E 35S-28S | land



ESCWA SMHI SWEDEN LAS ACSAD ISDR WMO RICCAR

CORDEX-MENA/Arab Ensemble Matrix

RCM (Institute)	GCM	Historical 1950-2005	RCP2.6 2006-2100	RCP4.5 2006-2100	RCP8.5 2006-2100
RCA4 (SMHI)	EC-Earth 50km	✓	✓	✓	✓
RCA4 (SMHI)	EC-Earth 25km	✓			✓
RCA4 (SMHI)	CNRM 50km	✓		✓	✓
RCA4 (SMHI)	GFDL-ESM 50km	✓		✓	✓
RCA4 (SMHI)	GFDL-ESM 25km	✓			✓
na (Kaust)	GFDL-ESM-1 25km	✓		✓	✓
na (Kaust)	GFDL-ESM-2 25km	✓		✓	✓
Remo (CSC)	MPI-ESM 50km	✓		✓	✓
RegCM4 (Kau)	HadGEM2 50km	✓		✓	✓
RegCM4 (Kau)	MPI-ESM 50km	✓		✓	✓
RegCM4 (Kau)	GFDL-ESM 50km	✓		✓	✓



✔ Completed ✔ Running ✔ Planned

Core: Monthly and seasonal output.

1	2-metre Air Temperature	K
2	Maximum 2-metre Air Temperature (monthly average of daily maximum)	K
3	Minimum 2-metre Air Temperature (monthly average of daily minimum)	K
4	Precipitation	kg/m^2/s
5	Mean Sea Level Pressure	Pa
6	2-metre Specific Humidity	1
7	10-metre Wind Speed	m/s
8	Maximum 10-metre Wind Speed (monthly average of daily max)	m/s
9	Total Cloud Cover	%
10	Sunshine Hours (duration when surface solar radiation flux exceeds 120 W/ m^2)	s
11	Surface Downwelling Shortwave Radiation	W/ m^2
12	Surface Downwelling Longwave Radiation	W/ m^2
13	Surface Latent Heat Flux	W/ m^2
14	Surface Sensible Heat Flux	W/ m^2
15	Upwelling Surface Shortwave Radiation	W/ m^2
16	Upwelling Longwave radiation	W/ m^2
17	Surface Evaporation	kg/ m^2/s
18	Soil Frozen Water Content	kg/ m^2
19	Surface Runoff	kg/ m^2/s
20	Total Runoff	kg/ m^2/s
21	Total Soil Moisture Content	kg/ m^2
22	Snow Amount	kg/ m^2
23	Snow Melt	kg/ m^2/s
24	TOA Outgoing Longwave Radiation	W/ m^2
25	TOA Incident Shortwave Radiation	W/ m^2
26	TOA Outgoing Shortwave Radiation	W/ m^2
27	Eastward 10-metre Wind Velocity	m/s
28	northward 10-metre Wind Velocity	m/s
29	Zonal (eastward) Wind at 850 hPa	m/s
30	Meridional (northward) Wind at 850 hPa	m/s
31	Temperature at 850 hPa	K
32	Specific Humidity at 850 hPa	1
33	Zonal (eastward) Wind at 500 hPa	m/s
34	Meridional (northward) Wind at 500 hPa	m/s
35	Geopotential Height at 500 hPa	m
36	Temperature at 500 hPa	K
37	Zonal (eastward) Wind at 200 hPa	m/s
38	Meridional (northward) Wind at 200 hPa	m/s
39	Temperature at 200 hPa	K
40	Geopotential at 200 hPa	m
41	Snow Area Fraction	%
42	Snow Depth	m
43	Sea Ice Fraction	%

CORDEX Specs

monthly

SMHI

Tier 1: Daily average output (for some variables minimum, maximum).

1	2-metre Air Temperature	K
2	Maximum 2-metre Air Temperature	K
3	Minimum 2-metre Air Temperature	K
4	Precipitation	kg/m2/s
5	Surface Pressure	Pa
6	Mean Sea Level Pressure	Pa
7	2-metre Specific Humidity	1
8	10-metre Wind Speed	m/s
9	Maximum 10-metre Wind Speed	m/s
10	Total Cloud Cover	%
11	Sunshine Hours	s
12	Surface Downwelling Shortwave Radiation	W/ m^2
13	Surface Downwelling Longwave Radiation	W/ m^2
14	Surface Latent Heat Flux	W/ m^2
15	Surface Sensible Heat Flux	W/ m^2
16	Surface Upwelling Shortwave Radiation	W/ m^2
17	Surface Upwelling Longwave radiation	W/ m^2
18	Surface Evaporation	kg/ m^2/s
19	Potential Evapotranspiration (if available)	kg/ m^2/s
20	Soil Frozen Water Content	kg/ m^2
21	Surface Runoff	kg/ m^2/s
22	Total Runoff	kg/ m^2/s
23	Total Soil Moisture Content	kg/ m^2
24	Snow Amount	kg/ m^2
25	Snow Melt	kg/ m^2/s
26	Maximum 1-hour Precipitation Rate within the 24 hour period	kg/ m^2/s
27	Convective Precipitation	kg/ m^2/s
28	TOA Outgoing Longwave Radiation	W/ m^2
29	TOA Incident Shortwave Radiation	W/ m^2
30	TOA Outgoing Shortwave Radiation	W/ m^2
31	Eastward 10-metre Wind Speed	m/s
32	Northward 10-metre Wind Speed	m/s
33	Maximum 10-metre GUST Wind Speed if available	m/s
34	Surface Downward Eastward Wind Stress	Pa
35	Surface Downward Northward Wind Stress	Pa
36	Surface (skin) Temperature	K
37	Atmospheric Boundary Layer Thickness	m
38	Column Water Vapour	m
39	Column Condensed (liquid+ice) Water Content	m
40	Column Ice Water Content	m
41	Zonal (eastward) Wind at 850 hPa	m/s
42	Meridional (northward) Wind at 850 hPa	m/s

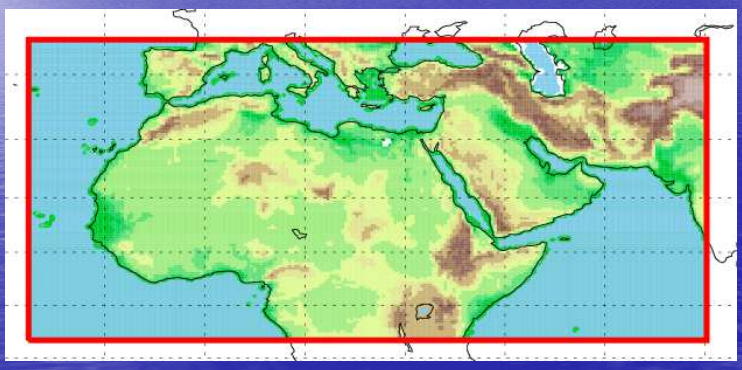
CORDEX Specs

43	Temperature at 850 hPa	K
44	Specific Humidity at 850 hPa	1
45	Zonal (eastward) wind at 500 hPa	m/s
46	Meridional (northward) wind at 500 hPa	m/s
47	Geopotential height at 500 hPa	m
48	Temperature at 500 hPa	K
49	Zonal (eastward) wind at 200 hPa	m/s
50	Meridional (northward) wind at 200 hPa	m/s
51	Temperature at 200 hPa	K
52	Geopotential at 200 hPa	m
53[a]	High Clouds (p<440 hPa) if available	%
54	Medium Clouds (680 hPa < p < 440 hPa) if available	%
55	Low Clouds (p>680 hPa) if available	%
56	Snow Area Fraction	%
57	Snow depth	m
58	Sea Ice Fraction	%
59	Snowfall Flux	kg/ m^2/s

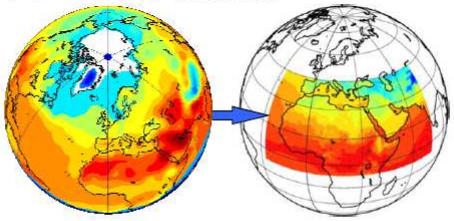
daily

SMHI

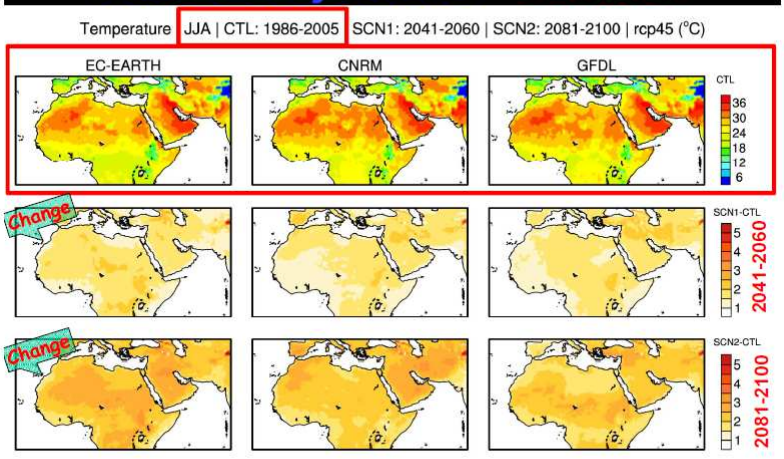
A first step within RICCAR was to establish a common modelling domain for regional downscaling



Using the common Arab domain for regional downscaling within CORDEX, several climate projections have been made

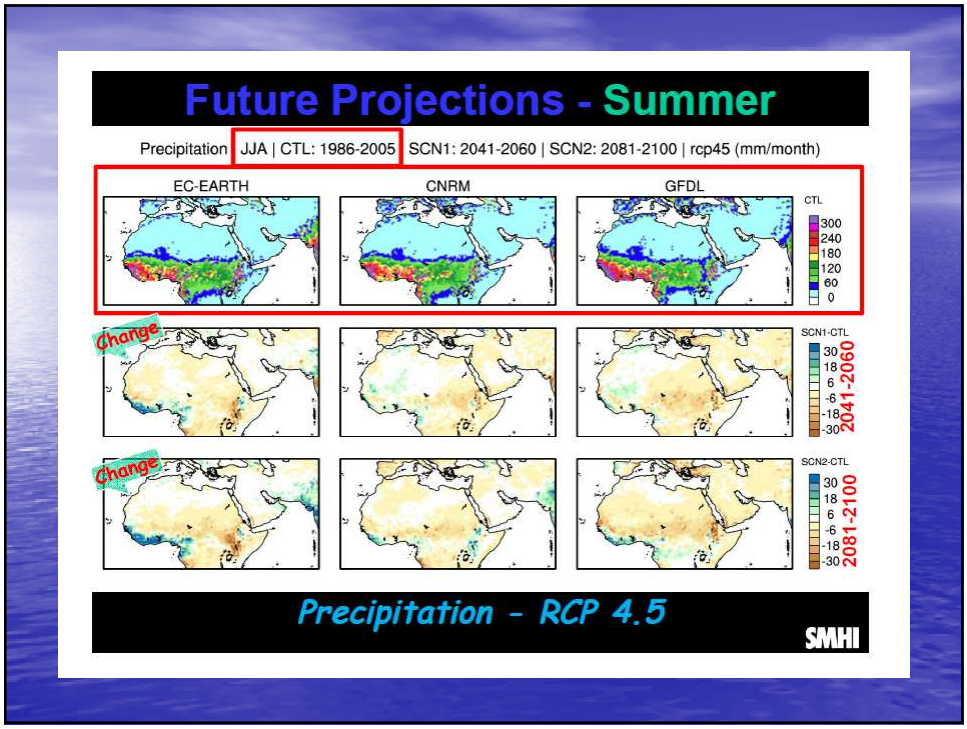


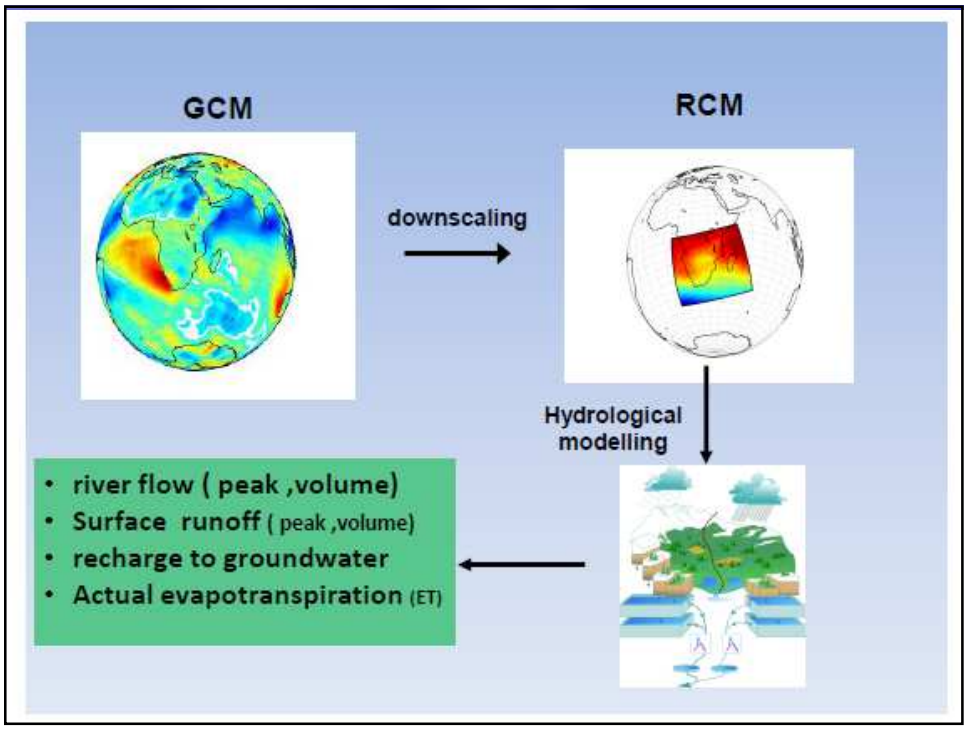
Future Projections - Summer



Temperature - RCP 4.5

SMHI


Future Projections - Summer
Precipitation
JJA | CTL: 1986-2005
SCN1: 2041-2060 | SCN2: 2081-2100 | rcp45 (mm/month)
EC-EARTH
CNRM
GFDL
CTL
300
240
180
120
60
0
Change
SCN1-CTL
30
18
6
-6
-18
-30
2041-2060
Change
SCN2-CTL
30
18
6
-6
-18
-30
2081-2100
Precipitation - RCP 4.5
SMHI


GCM
RCM
downscaling
Hydrological modelling
river flow (peak ,volume)
Surface runoff (peak ,volume)
recharge to groundwater
Actual evapotranspiration (ET)

Hydrological modeling

The following models were selected to simulate hydrological process over the Arab region

- **HYPE model (*HYdrological Predictions for the Environment*)**
- **VIC model**
- HEC-HMS

Selection criteria of the regional hydrological model

- The model should be one that can be applied over a range of catchment sizes from large to global
- The model should have been used for water-balance studies
- Adequate sophistication to simulate all relevant hydrologic processes, including arid area processes. In particular interactions between surface water and groundwater flows, and estimation of evapotranspiration. Representation should also include the river flow network.
- Should be able to output daily values
- The minimum input data requirements for the model must be easily available (data-poor catchment).
- The model should be able to use data from various global databases.
- The model must be readily and freely available with available documentation

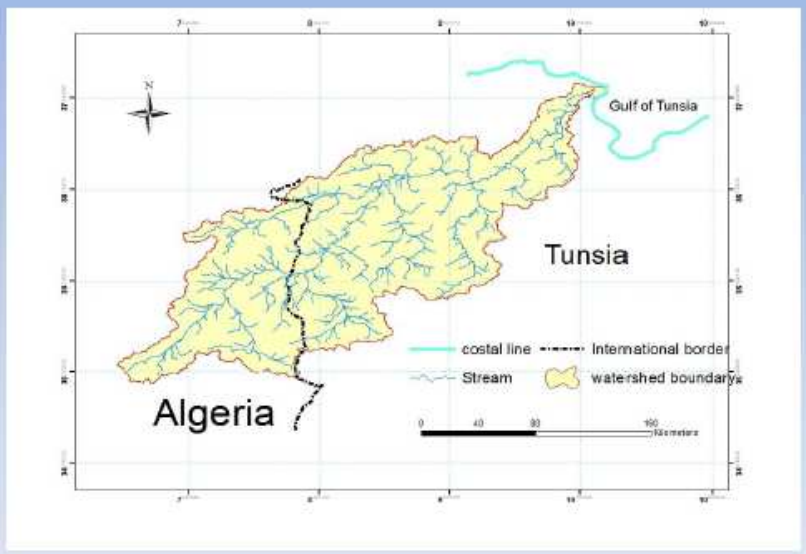
Source : presentation of Ann Johnell, EGM3 meeting, ESCWA 2011)

Test basins

test basins were selected from different area in the Arab region to evaluate and calibrate the selected models

- Mejerda watershed – Tunisia
- Wadi Dayqah - Sultanate of Oman
- Nahr el Kabir Al-Junoubi–Syria
- Nile river
- Euphrates river

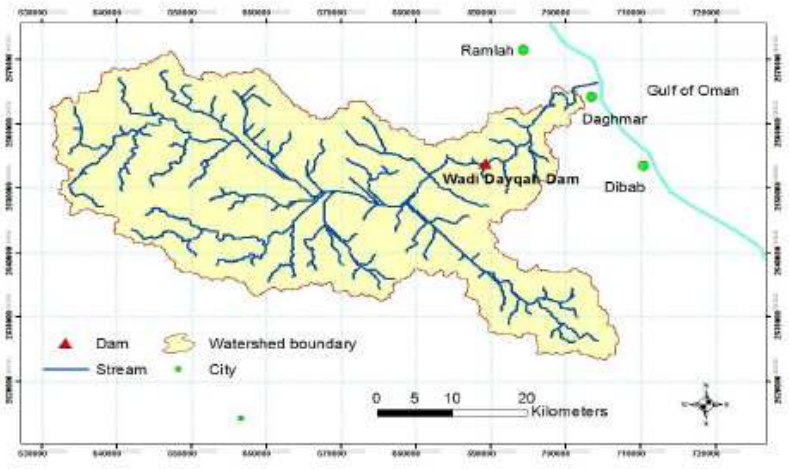
Medjerda River (Tunisia)



Basin Area =22070 km^2

Wadi Dayqah basin, Oman

located 60 km southeast of Muscat



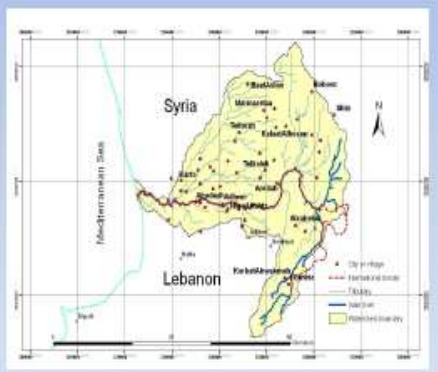
Basin area =1870 km^2

Nahr el Kabir Al-Junoubi

- The Nahr el Kabir Al-Junoubi constitutes the Lebanese Syrian borders

Nahr el Kabir Al-Junoubi

- The total water shed area (within Lebanon and Syria) is about 990 km^2 of which 295 km^2 lies in Lebanon

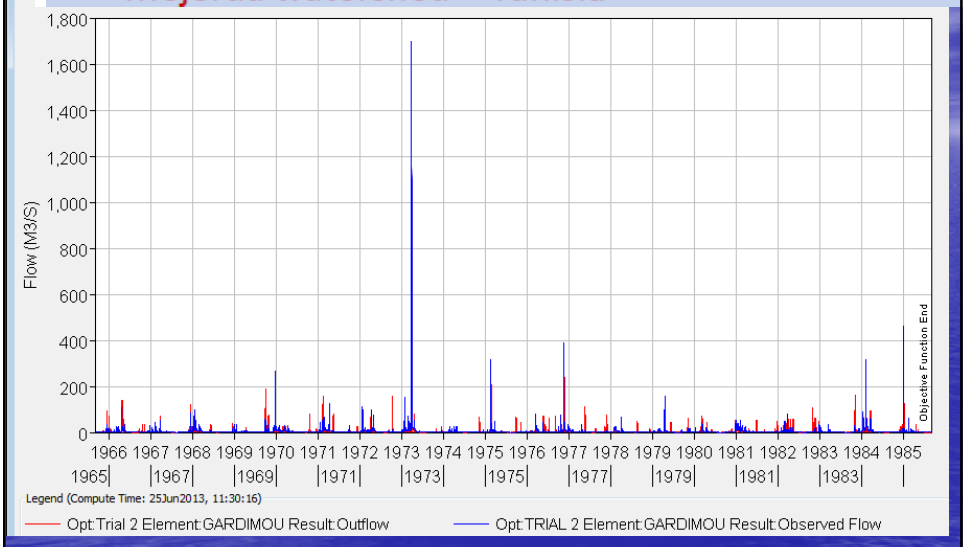


Nile Data

AL-Lith valley

- Located in the western part of Saudi Arabia along the Red Sea coast and is about 300 km south of Jeddah
- Area = 3000 km2

- Mejerda watershed – Tunisia



Optimized parameters

Optimized Parameter Results for Trial "Trial 2"

Project: hydrologicmodel Optimization Trial: Trial 2

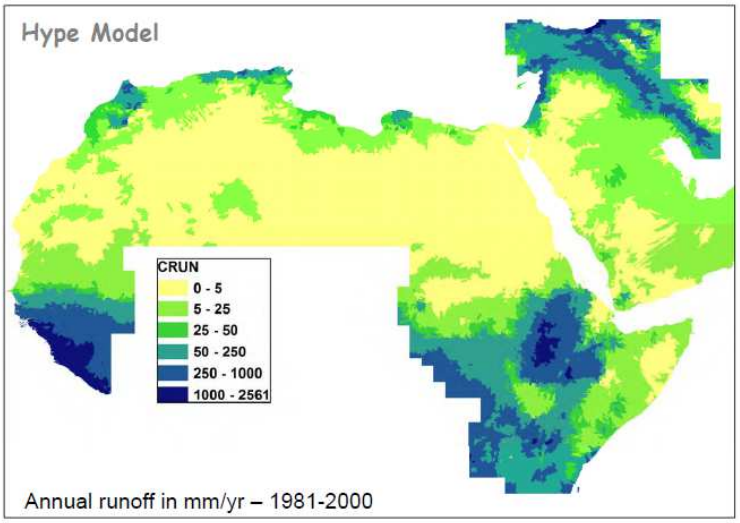
Start of Trial: 01Sep1965, 00:00
End of Trial: 31Aug1985, 00:00
Compute Time: 25Jun2013, 11:30:16

Basin Model: hydrologicmodel
Meteorologic Model: Met 1
Control Specifications: tttt_control

Element	Parameter	Units	Initial Value	Optimized Value	Objective Function Sensitivity
Gardimou	Soil Infiltration Rate	MM/HR	1.97	1.3386	-24.76
Gardimou	Soil Percolation Rate	MM/HR	0.653	0.44168	-37.25
Gardimou	Groundwater 1 Perco...	MM/HR	2.03	2.0701	-0.02
Gardimou	Groundwater 2 Perco...	MM/HR	2.03	2.0704	-0.00
Gardimou	Groundwater 1 Stora...	HR	10	0.26012	0.33
Gardimou	Groundwater 2 Stora...	HR	9.77	1.9299	0.00
Gardimou	Baseflow Initial Flow	M3/S	0.145	0.0286420	0.00
Gardimou	Baseflow Threshold R...		0.254	0.38100	0.00
Gardimou	Clark Storage Coeffic...	HR	37.85	38.335	-0.30
Gardimou	Clark Time of Concen...	HR	50.3	110.96	0.26
Gardimou	Recession Constant		0.51	0.47041	0.41

Hydrological Modelling

Runoff



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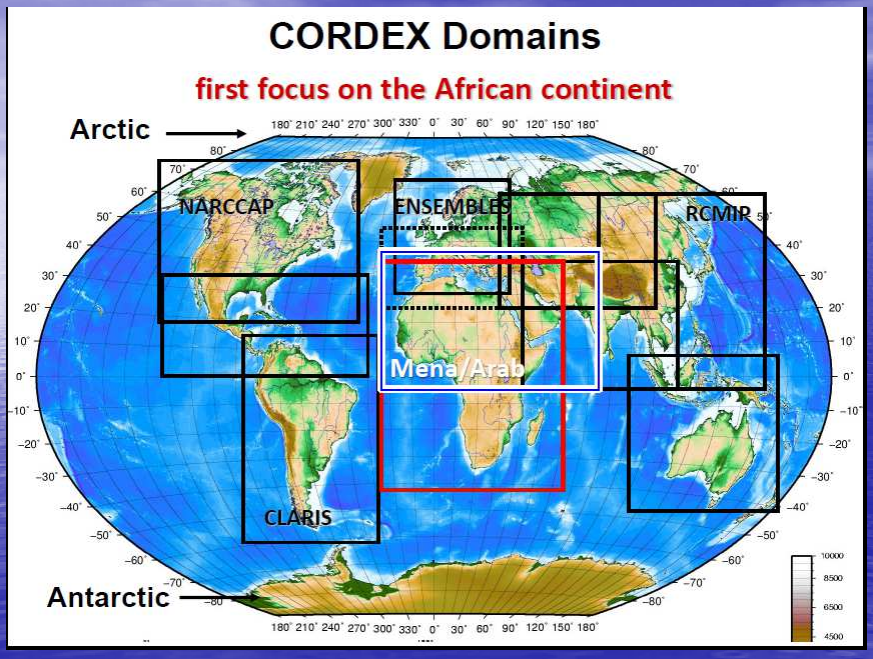
CORDEX

Coordinated Regional Climate Downscaling Experiment

- *CORDEX* is a program sponsored by World Climate Research Program (WRCP) to produce regional climate change scenarios globally, contributing to the IPCC AR5 and to the climate community
- It is a multi-region, multi emission scenario, ensemble of RCMs & GCMs
- It is Freely accessible

CORDEX Domains

first focus on the African continent



CORDEX-Mena projections were published on ESGF last month!
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NCI Node
About the datanode/NSC
The SMHI-LIU-NSC ESGF datanode at the National Supercomputer Centre, Linköping, is Sweden's first datanode in the ESGF framework. It hosts climate data produced by the Swedish Meteorological and Hydrological Institute (SMHI). NSC is an independent organization within Linköping University (LIU), and is funded by the Swedish Research Council via SNIC (Swedish National Infrastructure for Computing).
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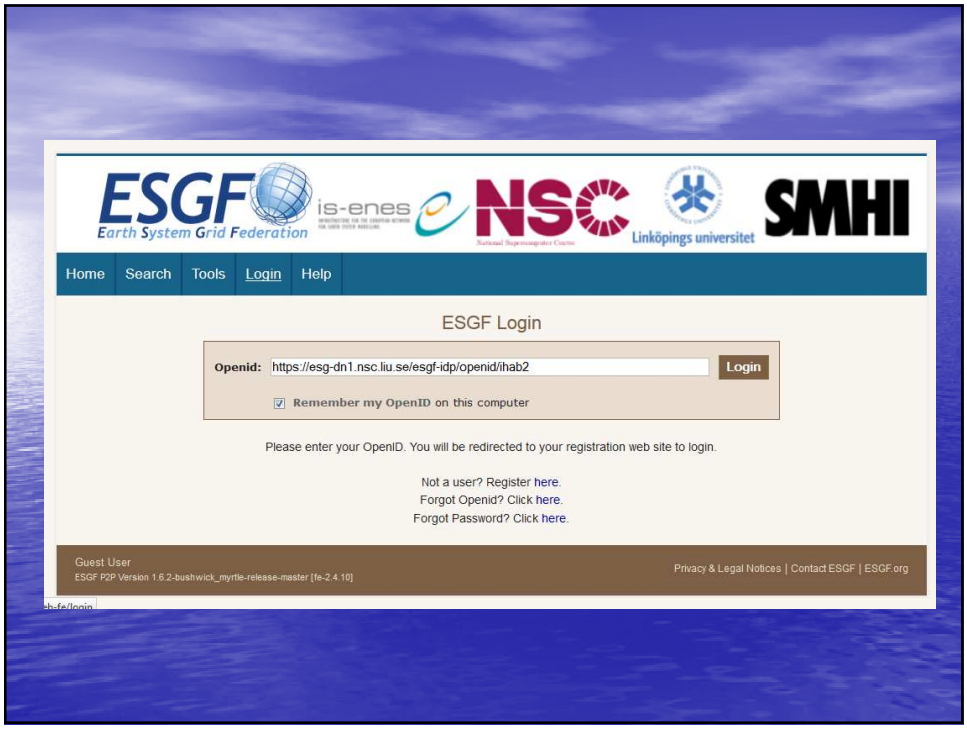
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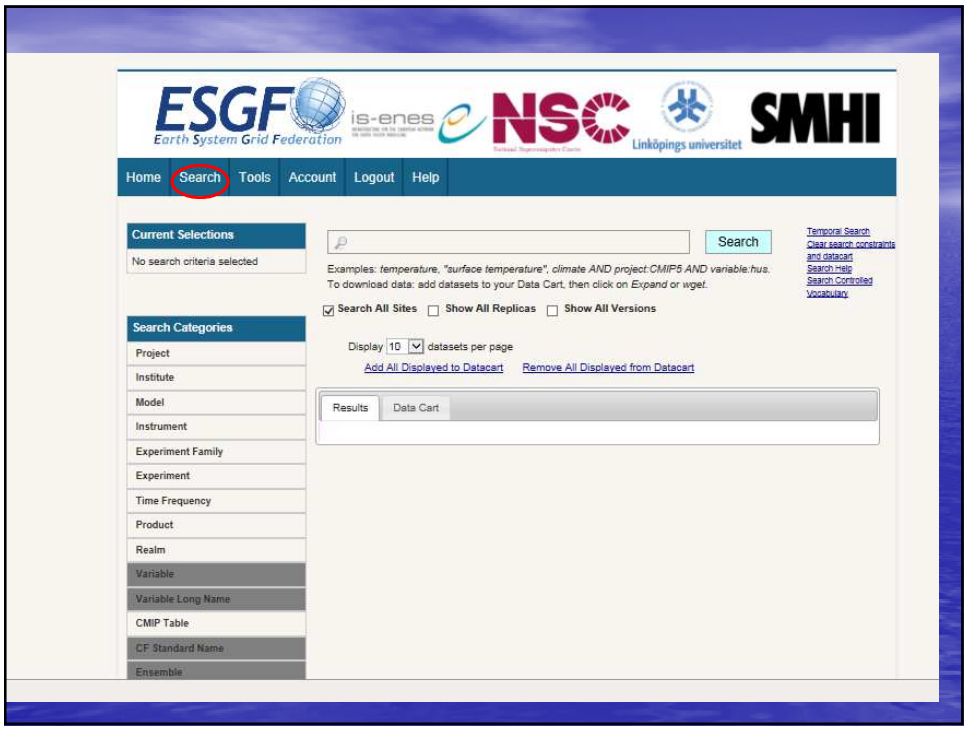
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Show All Versions
Search Categories
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Institute
Model
Instrument
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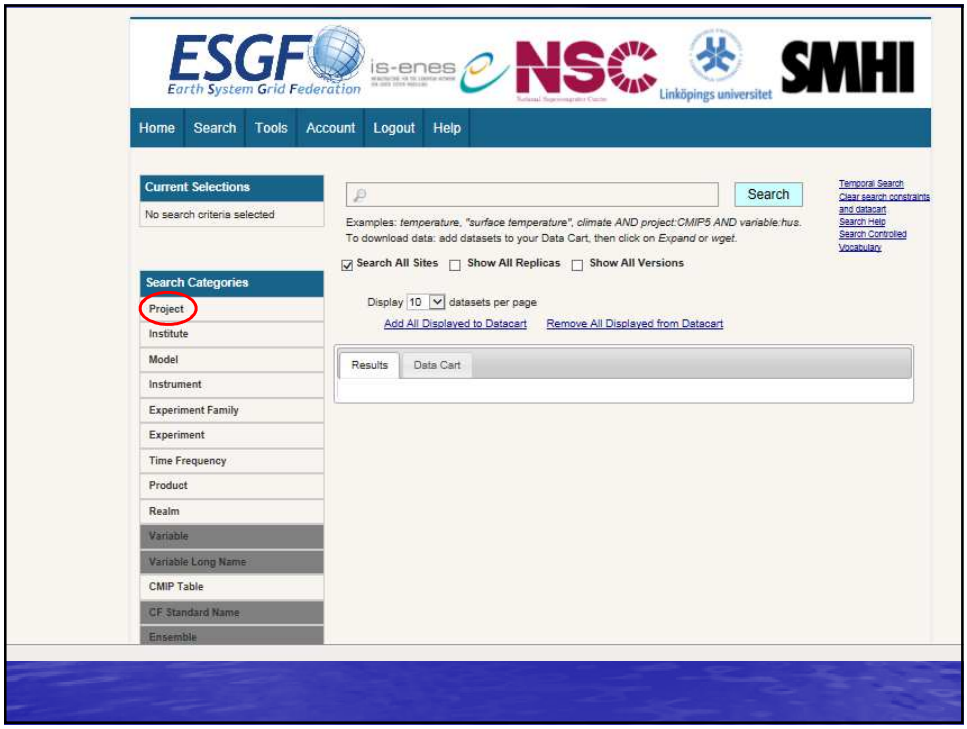
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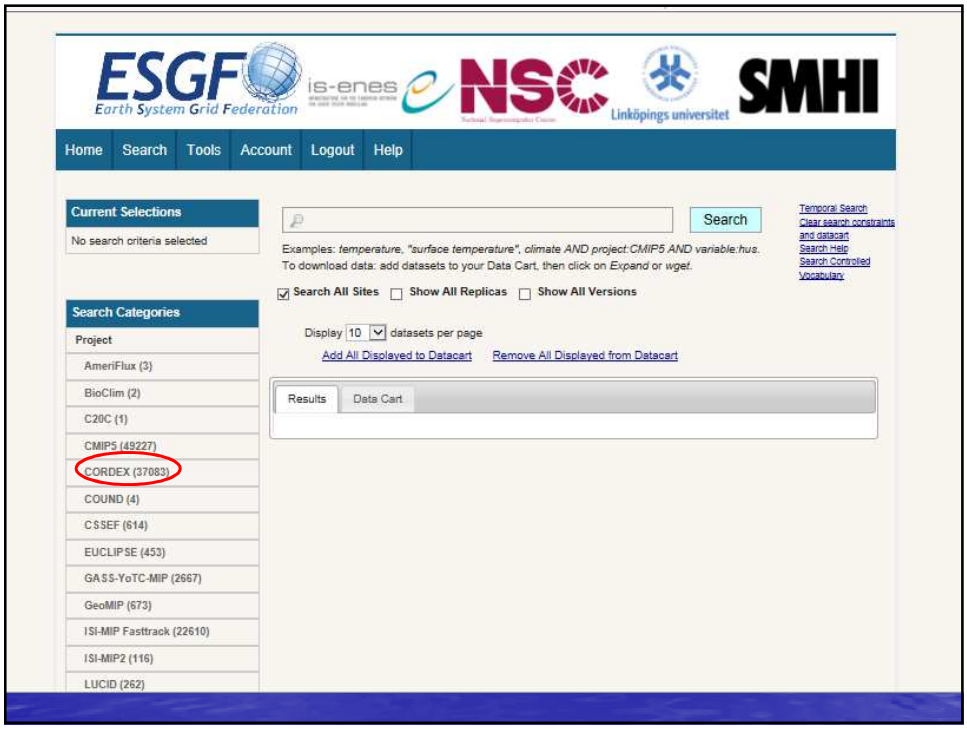
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Examples: temperature, "surface temperature", climate AND project:CMIP5 AND variable:hus.
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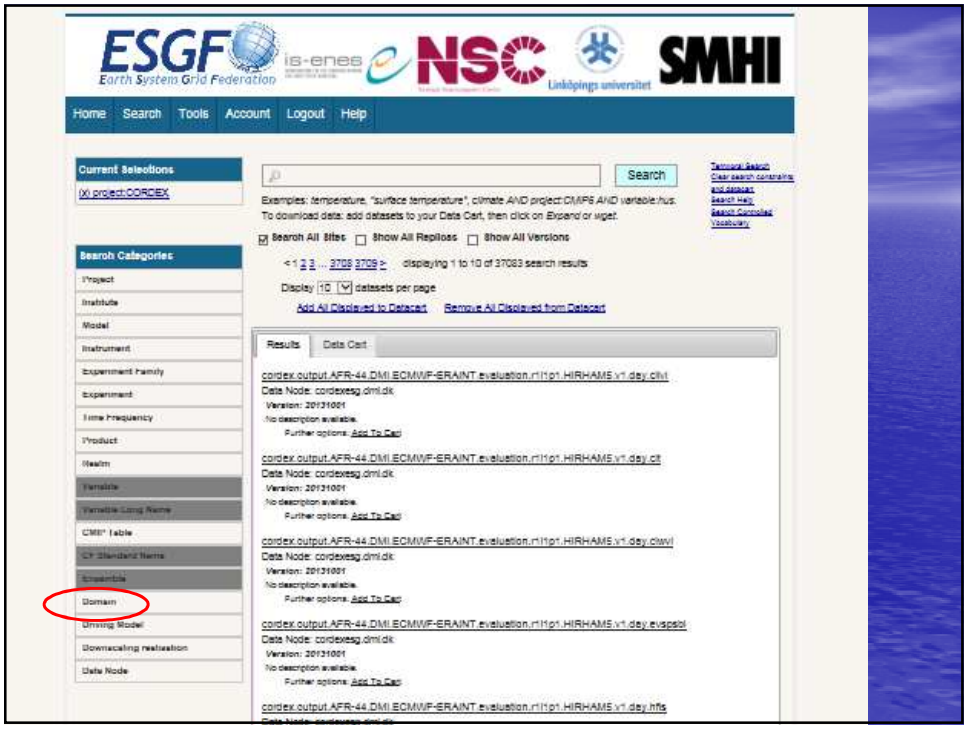
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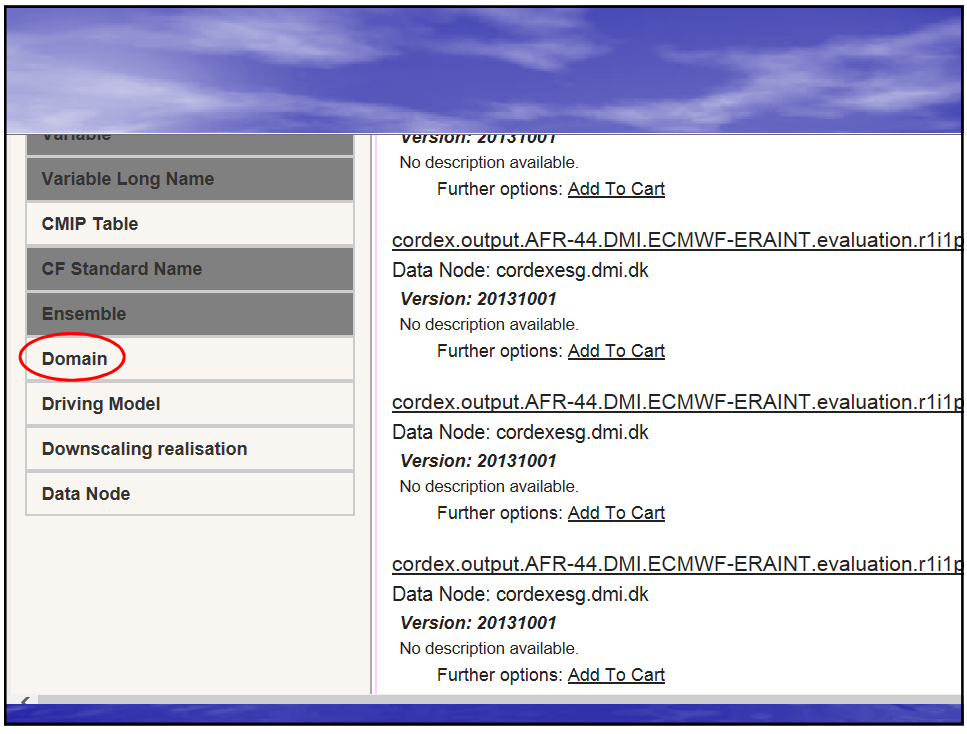
Variable Long Name
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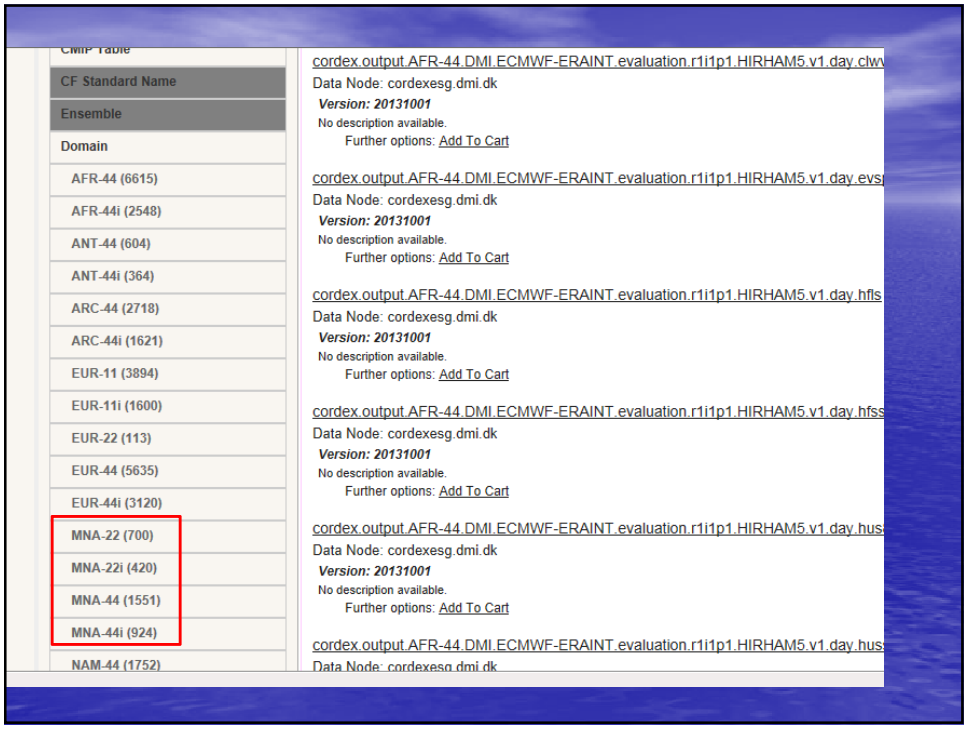
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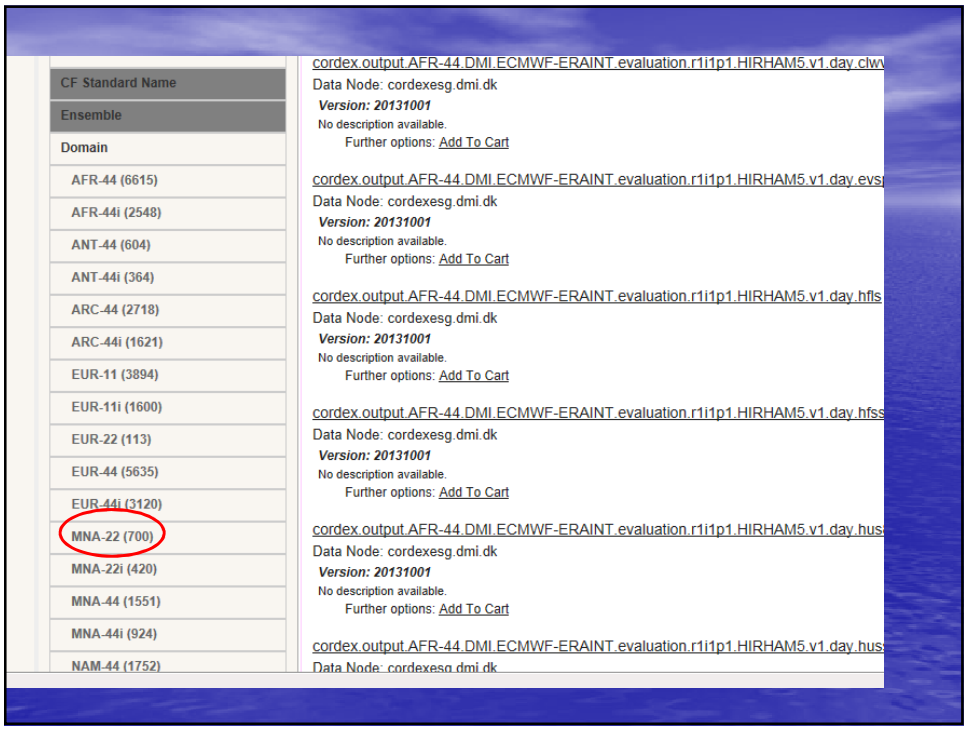
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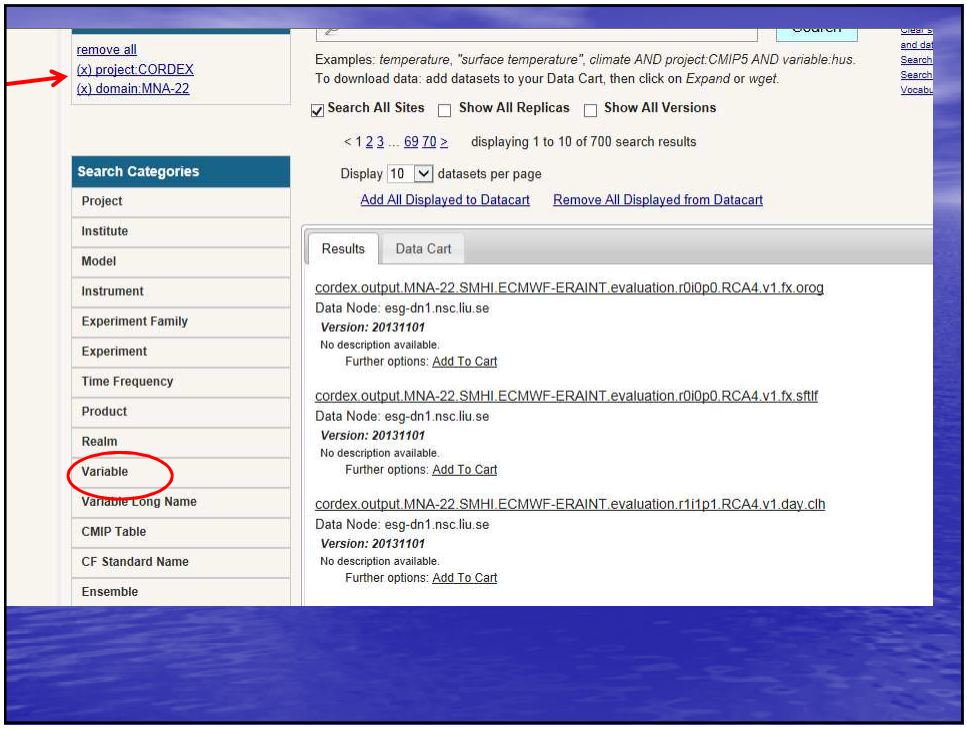
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Institute
Model
Instrument
Experiment Family
Experiment
Time Frequency
Product
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Variable
Variable Long Name
CMIP Table
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Ensemble
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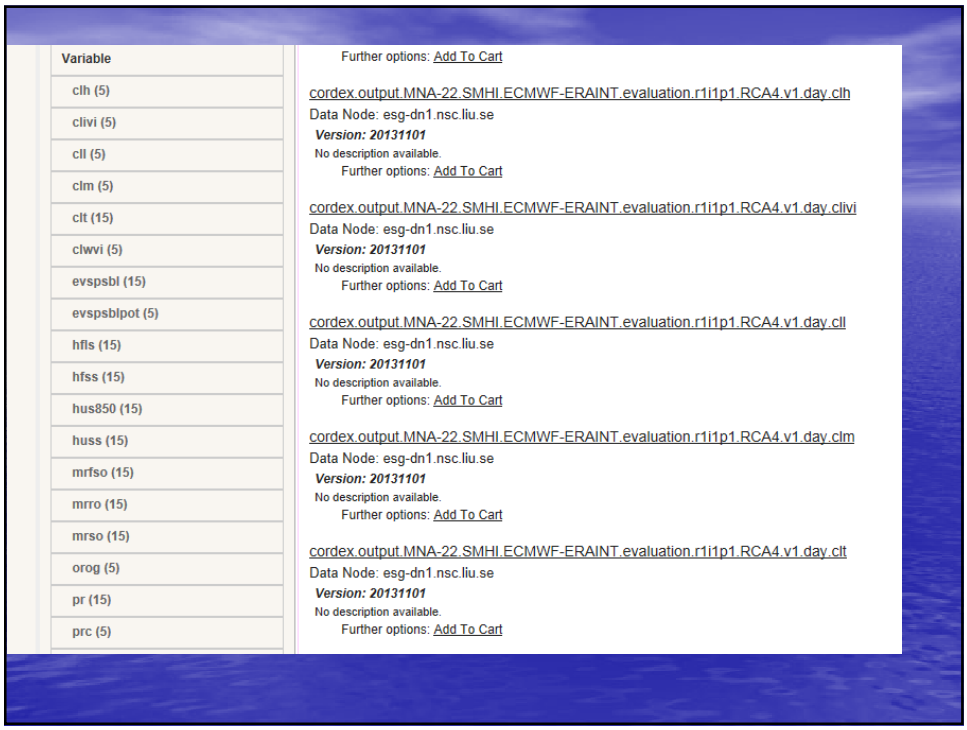
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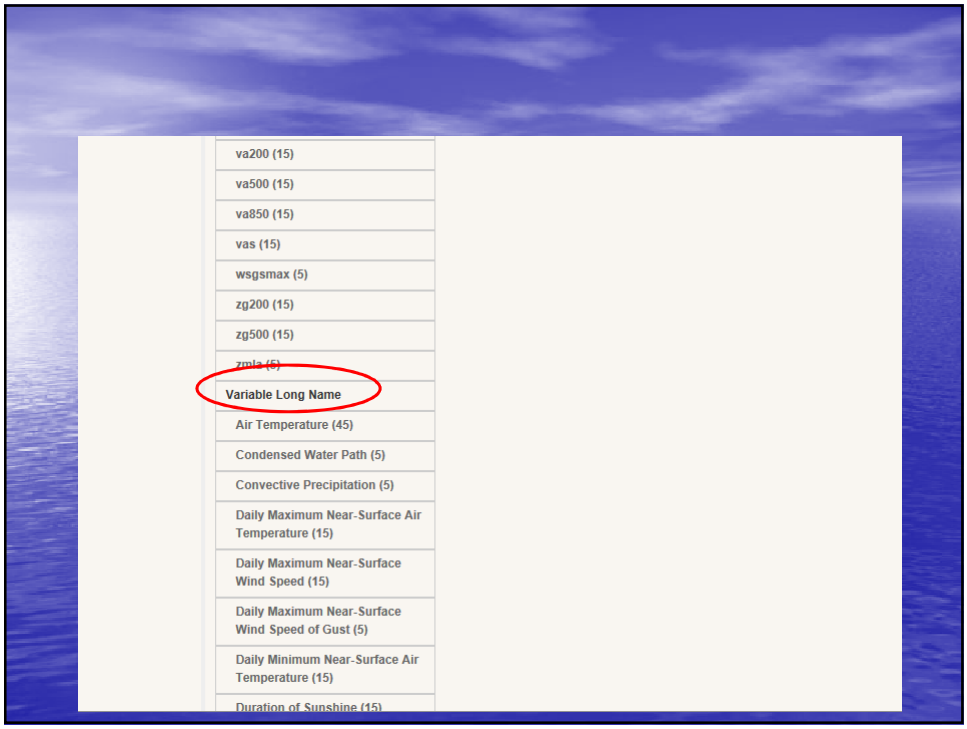
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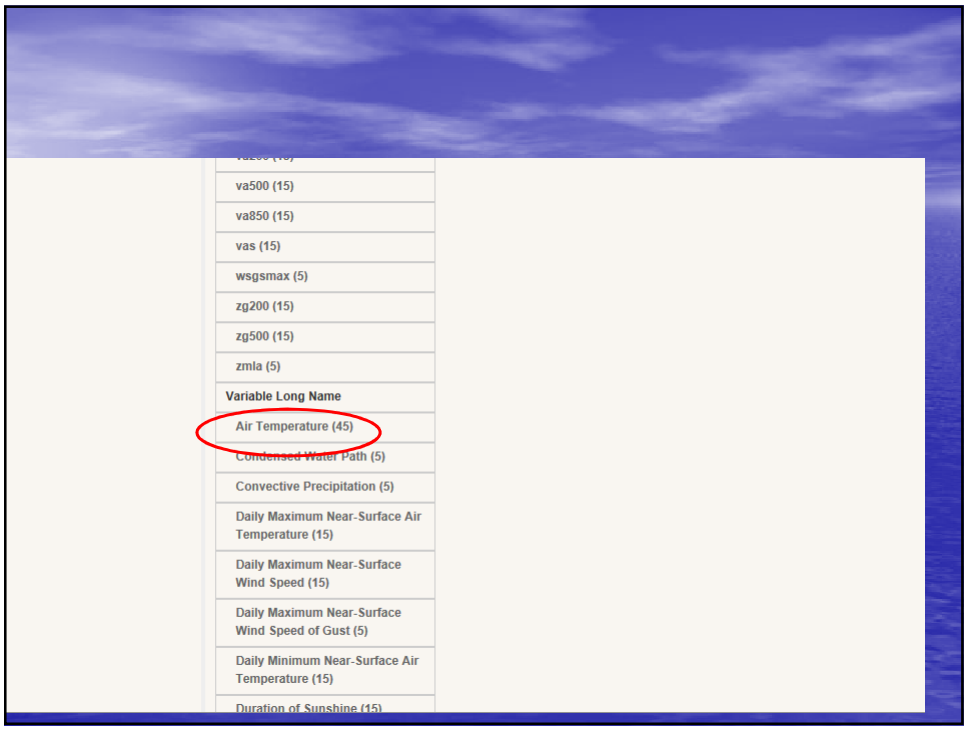
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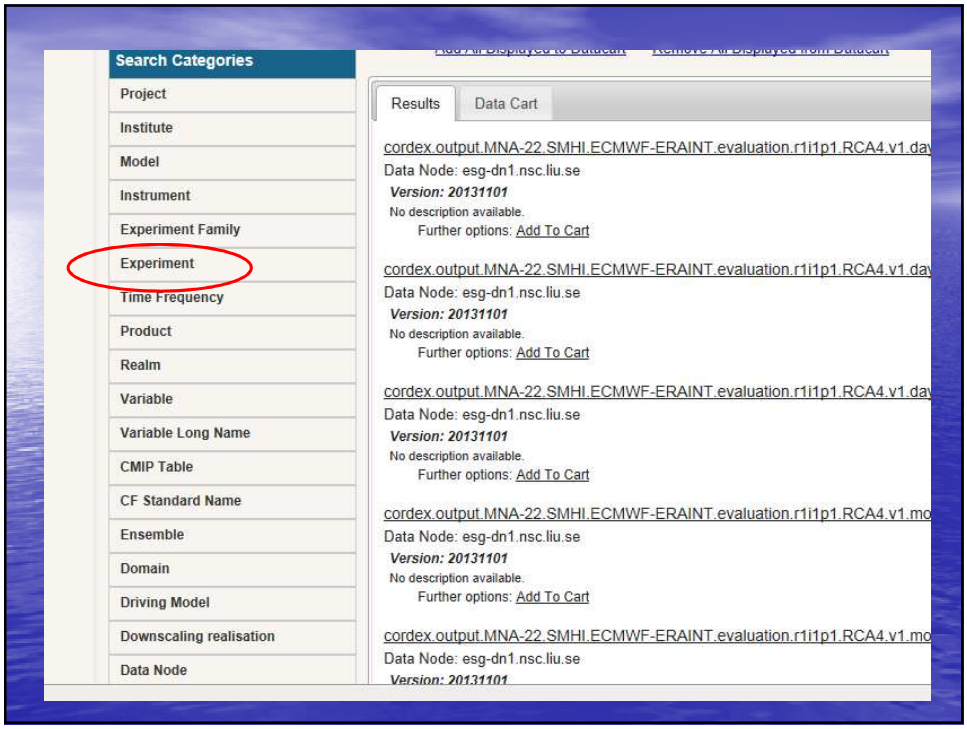
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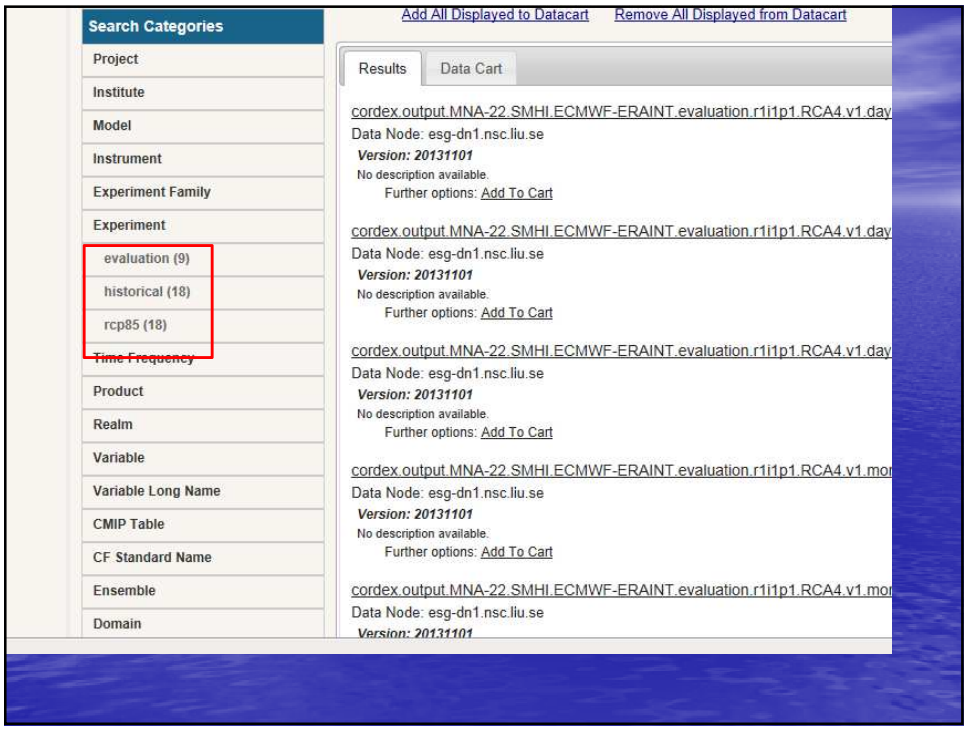
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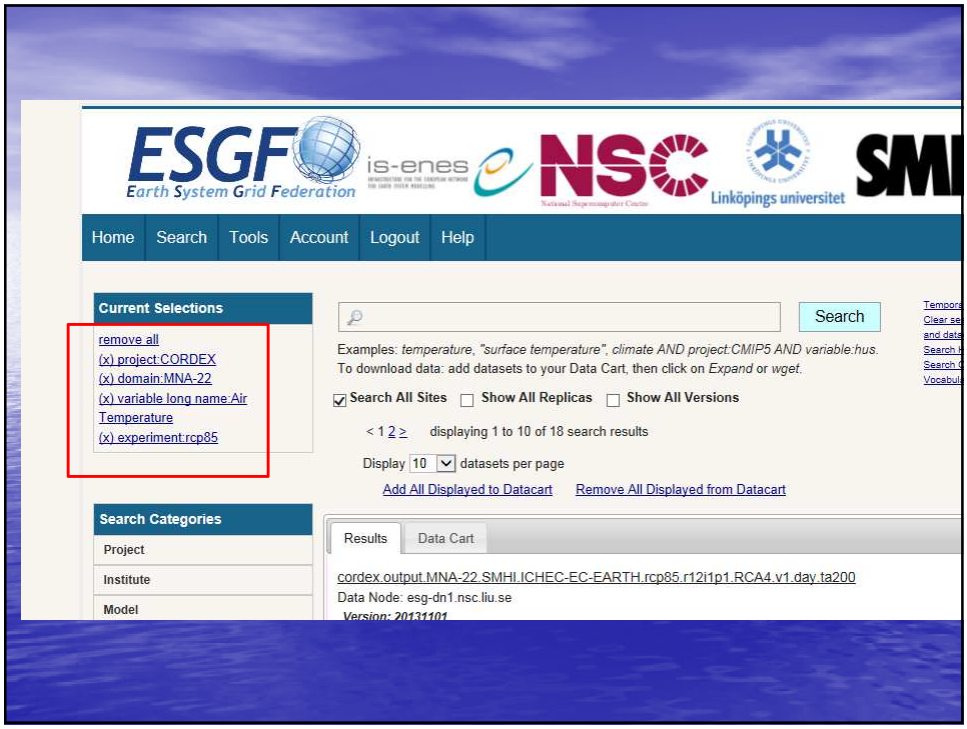
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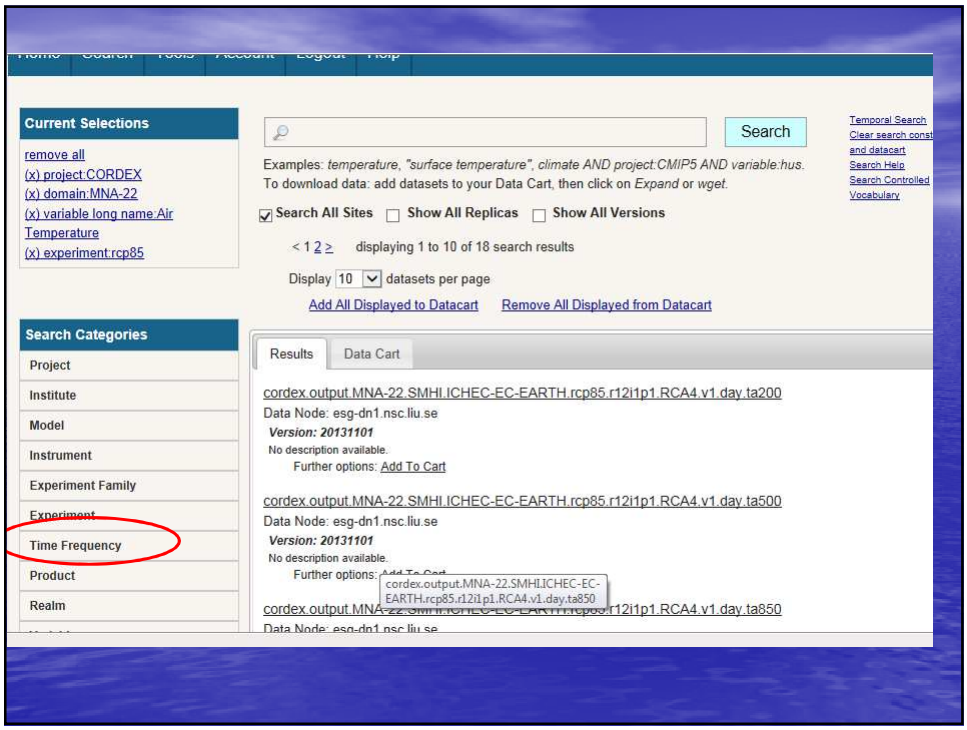
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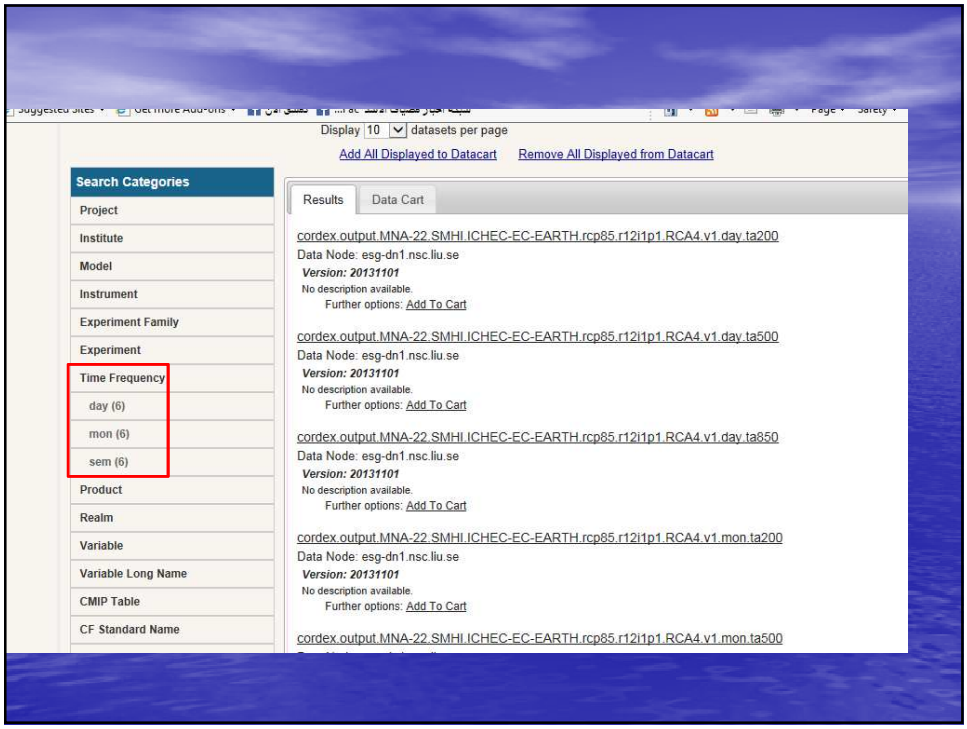
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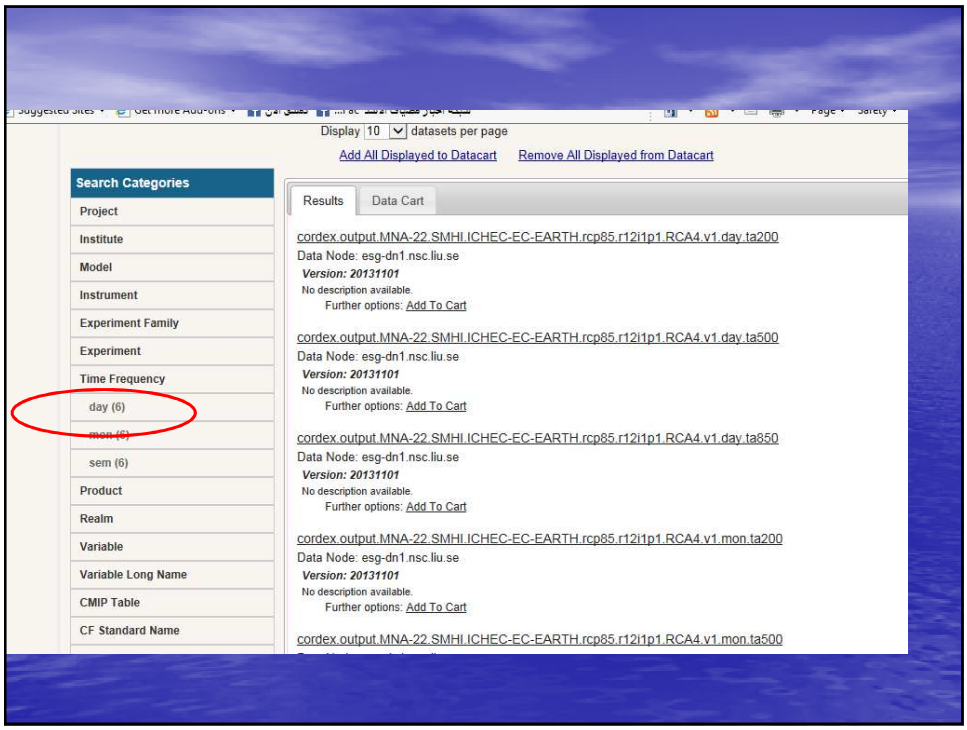
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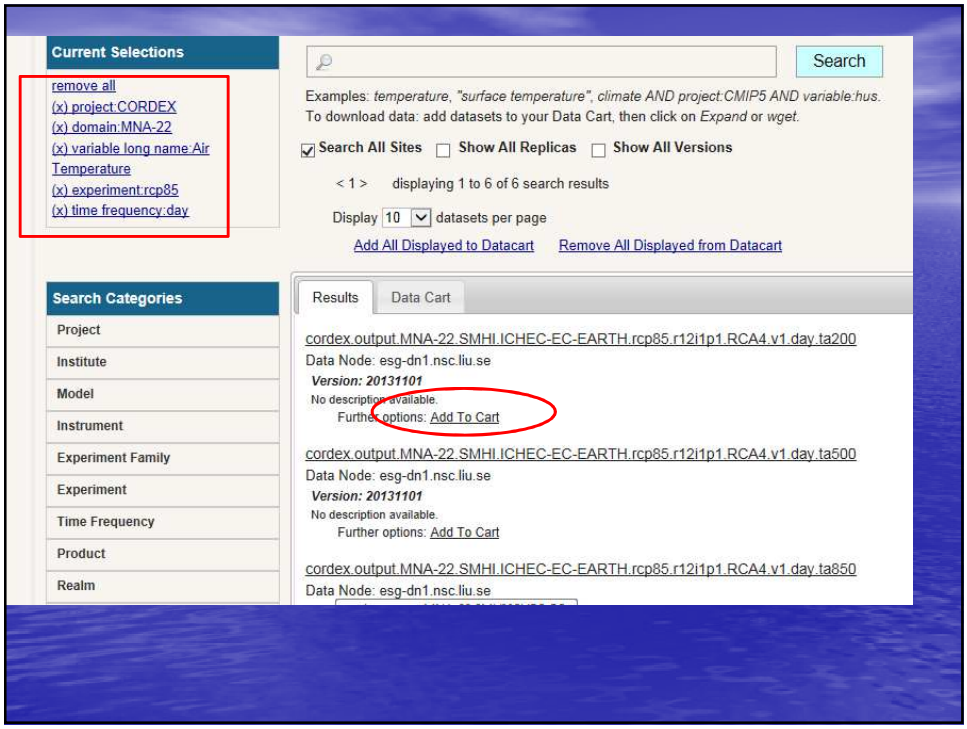
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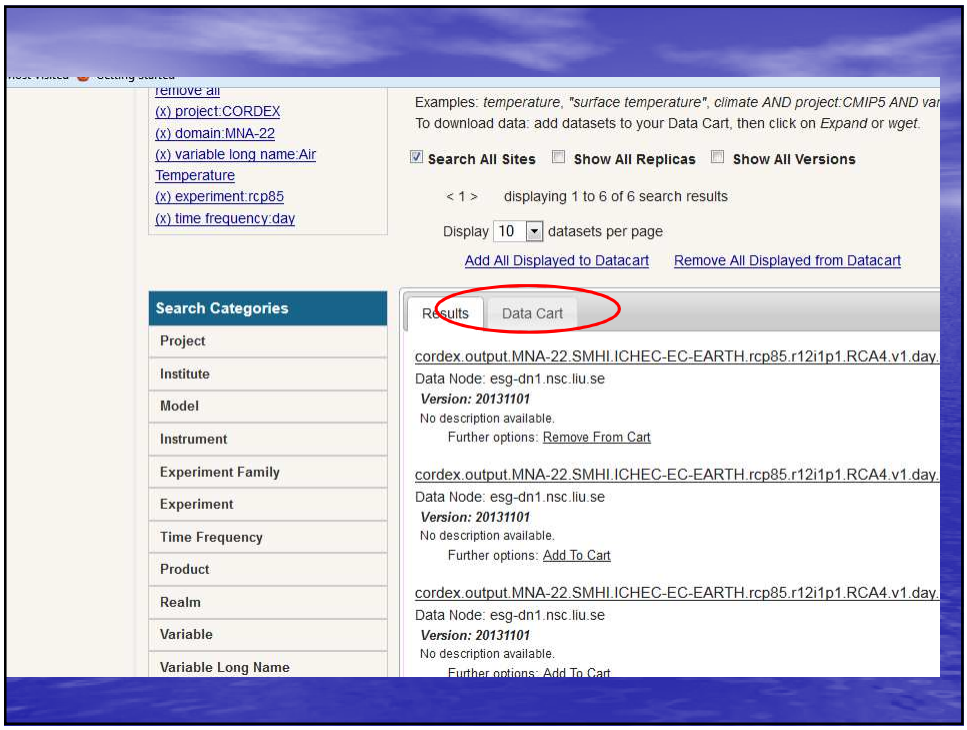
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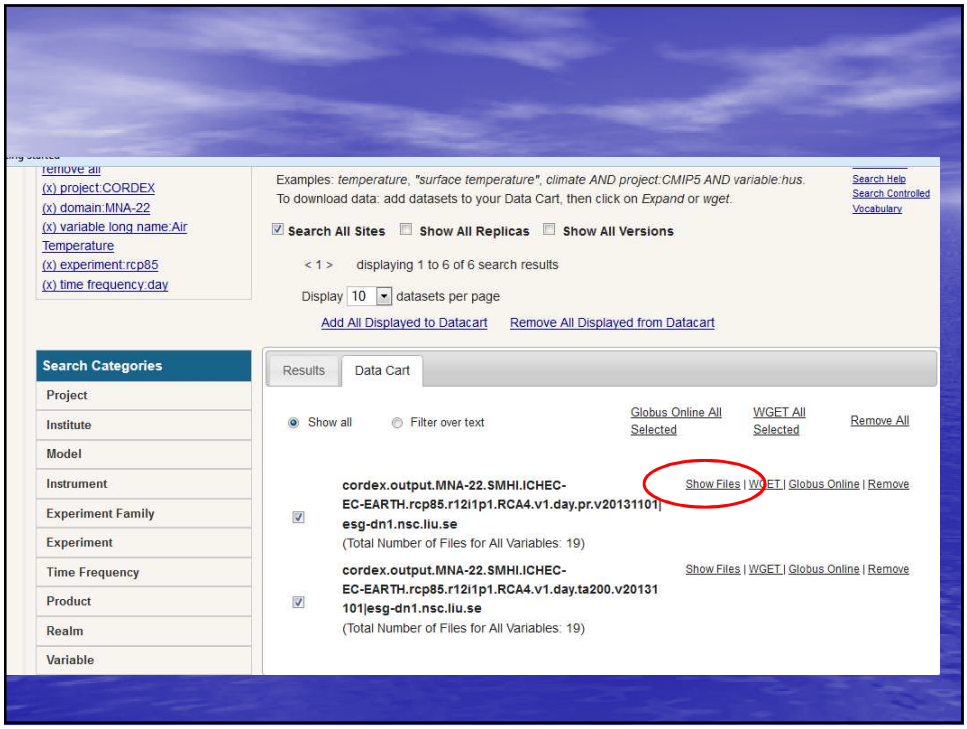
Data Node: esg-dn1.nsc.liu.se
Version: 20131101
No description available.
Further options: Add To Cart


remove all
(x) project:CORDEX
(x) domain:MNA-22
(x) variable long name:Air Temperature
(x) experiment:rcp85
(x) time frequency:day
Examples: temperature, "surface temperature", climate AND project:CMIP5 AND variable:hus.
To download data: add datasets to your Data Cart, then click on Expand or wget.
Search Help
Search Controlled Vocabulary
Search All Sites
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Show All Versions
< 1 > displaying 1 to 6 of 6 search results
Display 10 datasets per page
Add All Displayed to Datacart
Remove All Displayed from Datacart
Search Categories
Project
Institute
Model
Instrument
Experiment Family
Experiment
Time Frequency
Product
Realm
Variable
Results
Data Cart
Show all
Filter over text
Globus Online All Selected
WGET All Selected
Remove All
cordex.output.MNA-22.SMHI.ICHEC-EC-EARTH.rcp85.r12i1p1.RCA4.v1.day.pr.v20131101|esg-dn1.nsc.liu.se
Show Files | WGET | Globus Online | Remove
(Total Number of Files for All Variables: 19)
cordex.output.MNA-22.SMHI.ICHEC-EC-EARTH.rcp85.r12i1p1.RCA4.v1.day.ta200.v20131101|esg-dn1.nsc.liu.se
Show Files | WGET | Globus Online | Remove
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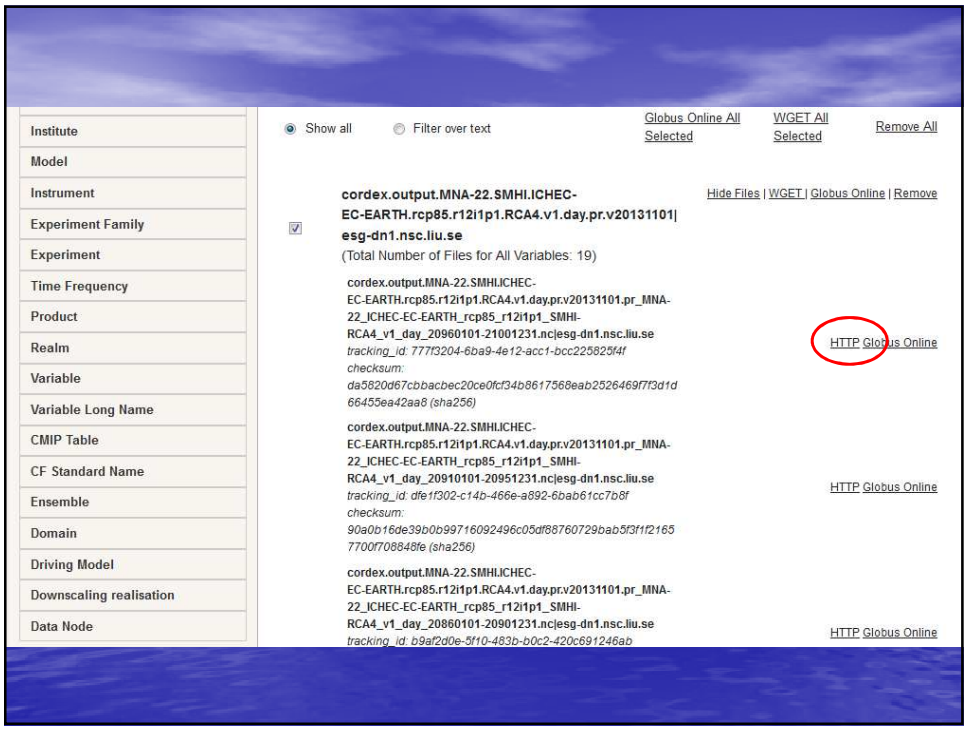
Institute
Model
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Driving Model
Downscaling realisation
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Show all
Filter over text
Globus Online All Selected
WGET All Selected
Remove All
cordex.output.MNA-22.SMHI.ICHEC-EC-EARTH.rcp85.r12i1p1.RCA4.v1.day.pr.v20131101|esg-dn1.nsc.liu.se
Hide Files | WGET | Globus Online | Remove
(Total Number of Files for All Variables: 19)
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HTTP Globus Online
cordex.output.MNA-22.SMHI.ICHEC-EC-EARTH.rcp85.r12i1p1.RCA4.v1.day.pr.v20131101.pr_MNA-22_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1_day_20910101-20951231.nc|esg-dn1.nsc.liu.se
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HTTP Globus Online
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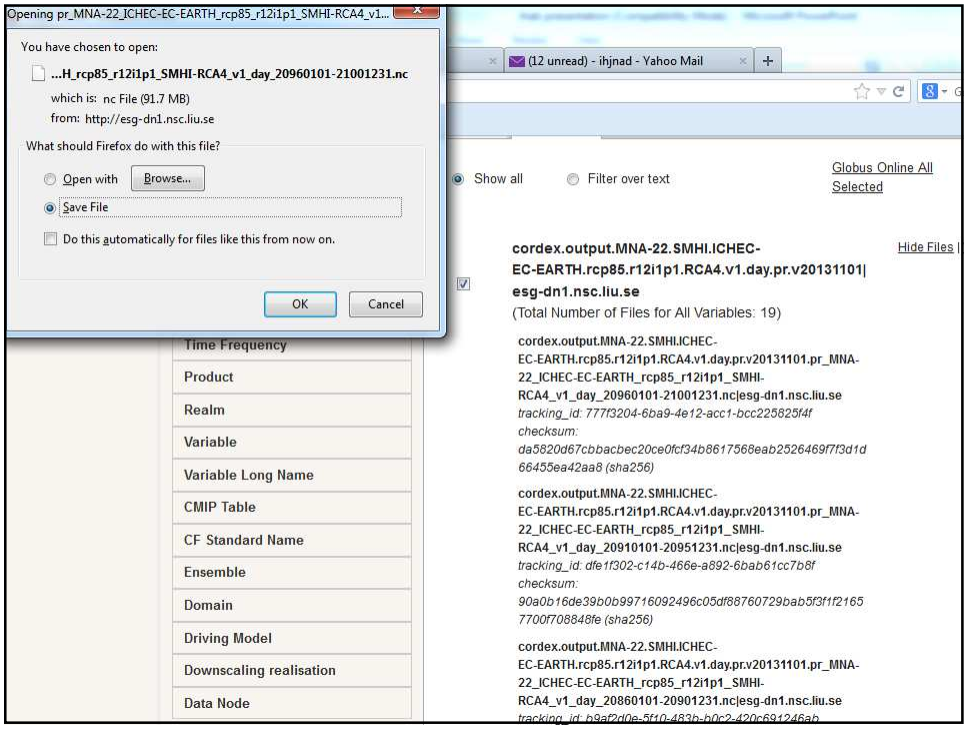
HTTP Globus Online


Opening pr_MNA-22_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1...
You have chosen to open:
...H_rcp85_r12i1p1_SMHI-RCA4_v1_day_20960101-21001231.nc
which is: nc File (91.7 MB)
from: http://esg-dn1.nsc.liu.se
What should Firefox do with this file?
Open with
Browse...
Save File
Do this automatically for files like this from now on.
OK
Cancel
(12 unread) - ihjnad - Yahoo Mail
Show all
Filter over text
Globus Online All Selected
Hide Files
Time Frequency
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Variable Long Name
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CF Standard Name
Ensemble
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Driving Model
Downscaling realisation
Data Node
cordex.output.MNA-22.SMHI.ICHEC-EC-EARTH.rcp85.r12i1p1.RCA4.v1.day.pr.v20131101|esg-dn1.nsc.liu.se
(Total Number of Files for All Variables: 19)
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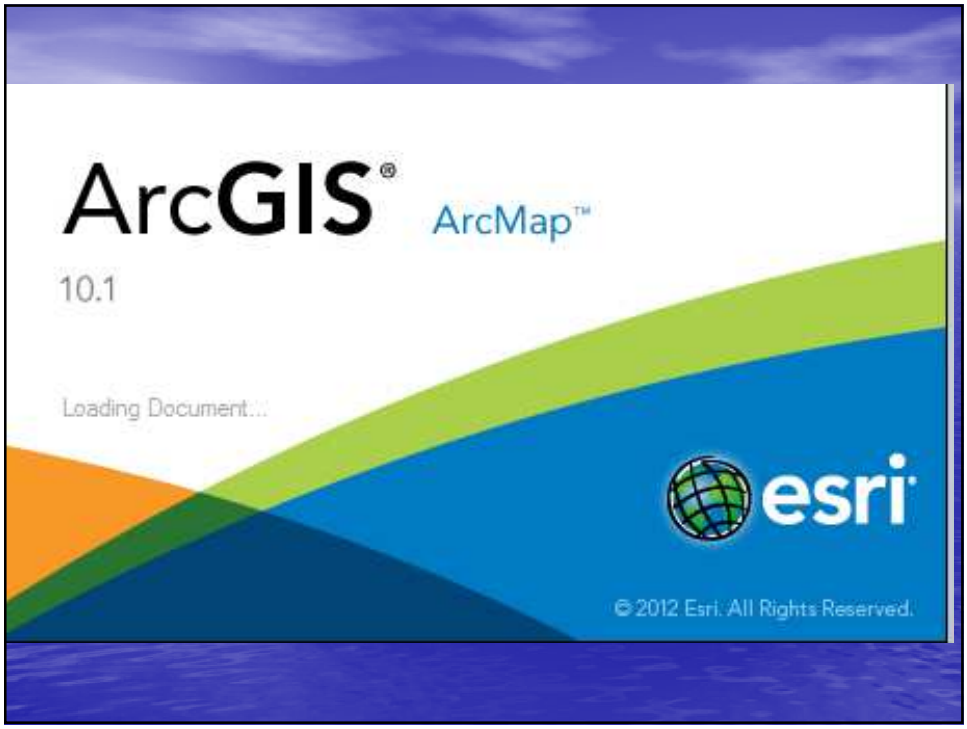
ta200_MNA-22_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4_v1_day_20960101-21001231.nc
What is NetCDF?
NetCDF (network Common Data Form)
A platform independent format for representing multi-dimensional array-orientated scientific data.
Y
Time
X


ArcGIS®
ArcMap™
10.1
Loading Document...
esri
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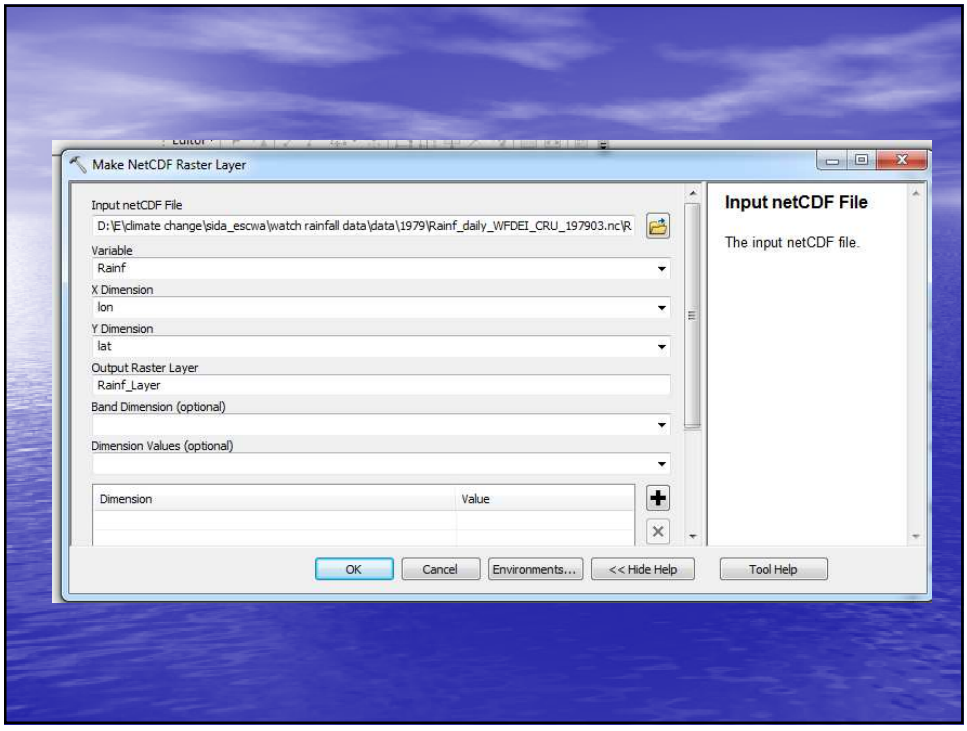
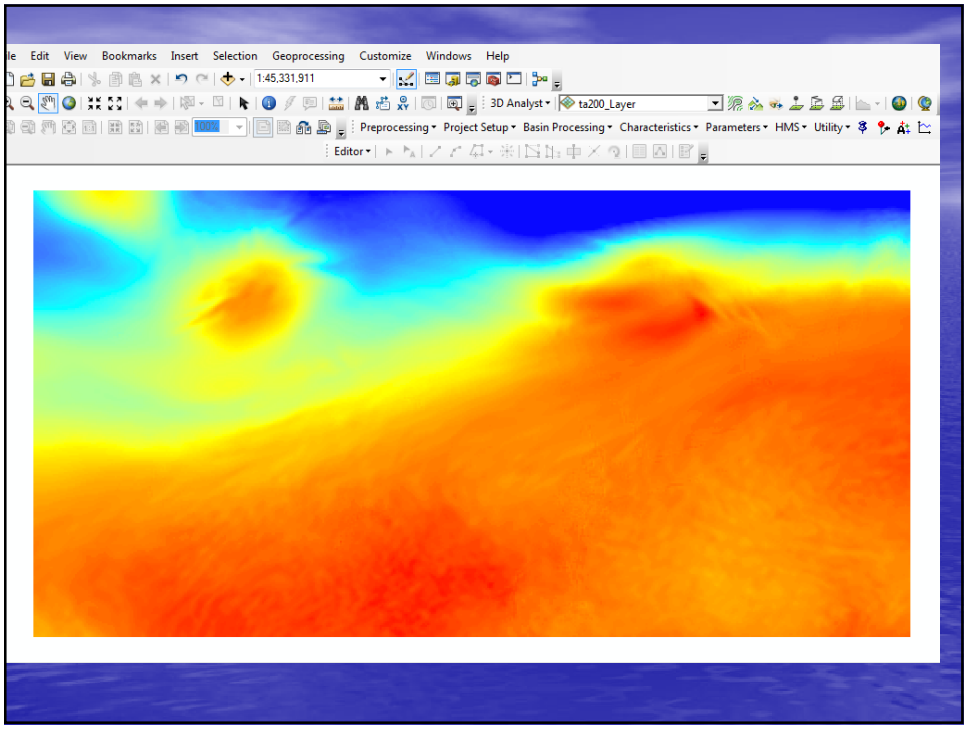
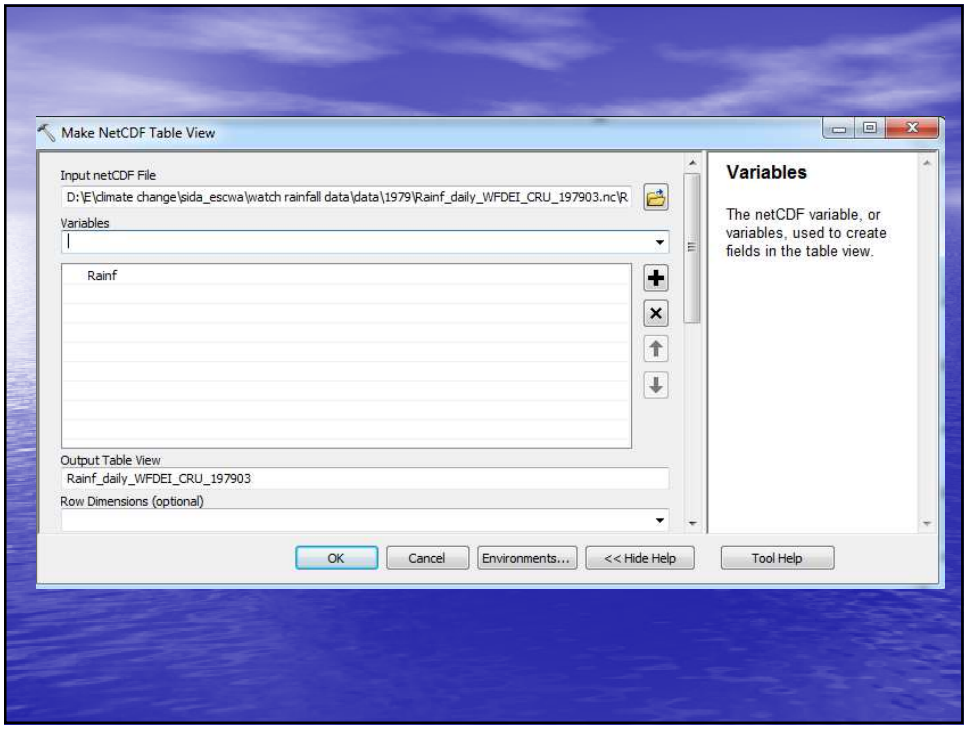

Make NetCDF Raster Layer
Input netCDF File
D:\E\climate change\sida_escwa\watch rainfall data\data\1979\Rainf_daily_WFDEI_CRU_197903.nc\R
Variable
Rainf
X Dimension
lon
Y Dimension
lat
Output Raster Layer
Rainf_Layer
Band Dimension (optional)
Dimension Values (optional)
Dimension
Value
OK
Cancel
Environments...
<< Hide Help
Tool Help
Input netCDF File
The input netCDF file.


Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:45,331,911
3D Analyst
ta200_Layer
Preprocessing Project Setup Basin Processing Characteristics Parameters HMS Utility
Editor


Make NetCDF Table View
Input netCDF File
D:\E\climate change\sida_escwa\watch rainfall data\data\1979\Rainf_daily_WFDEI_CRU_197903.nc\R
Variables
Rainf
Output Table View
Rainf_daily_WFDEI_CRU_197903
Row Dimensions (optional)
OK
Cancel
Environments...
<< Hide Help
Tool Help
Variables
The netCDF variable, or variables, used to create fields in the table view.

ta200_MNA-22_ICHEC-EC-EARTH_

OID	time	ta200
1	1/1/2096 12:00:00 PM	220.4823
2	1/2/2096 12:00:00 PM	218.2572
3	1/3/2096 12:00:00 PM	217.2384
4	1/4/2096 12:00:00 PM	214.345
5	1/5/2096 12:00:00 PM	214.2417
6	1/6/2096 12:00:00 PM	218.5714
7	1/7/2096 12:00:00 PM	217.0804
8	1/8/2096 12:00:00 PM	222.1257
9	1/9/2096 12:00:00 PM	215.7656
10	1/10/2096 12:00:00 PM	213.8888
11	1/11/2096 12:00:00 PM	216.6205
12	1/12/2096 12:00:00 PM	219.8328
13	1/13/2096 12:00:00 PM	217.542
14	1/14/2096 12:00:00 PM	216.5723
15	1/15/2096 12:00:00 PM	216.184
16	1/16/2096 12:00:00 PM	215.2609
17	1/17/2096 12:00:00 PM	214.0273
18	1/18/2096 12:00:00 PM	213.6782
19	1/19/2096 12:00:00 PM	213.0831
20	1/20/2096 12:00:00 PM	217.3637
21	1/21/2096 12:00:00 PM	218.2002
22	1/22/2096 12:00:00 PM	214.9776
23	1/23/2096 12:00:00 PM	213.6382
24	1/24/2096 12:00:00 PM	215.0868
25	1/25/2096 12:00:00 PM	215.5897
26	1/26/2096 12:00:00 PM	216.4209

Thanks