# Regional climate prediction system for south Caucasus region

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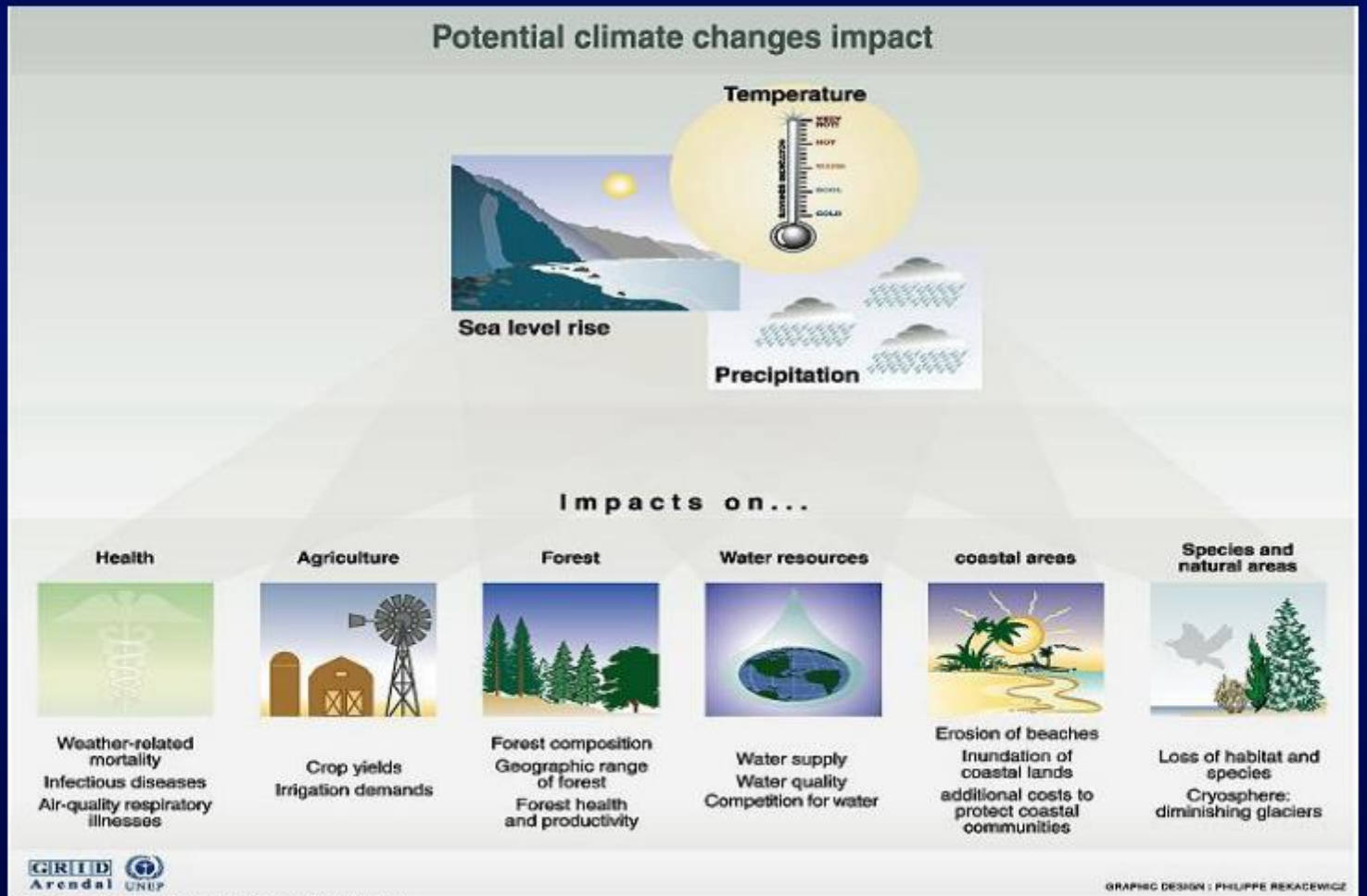
# Regional climate information is needed for Impact/Adaptation/Vulnerability (IAV) assessment studies



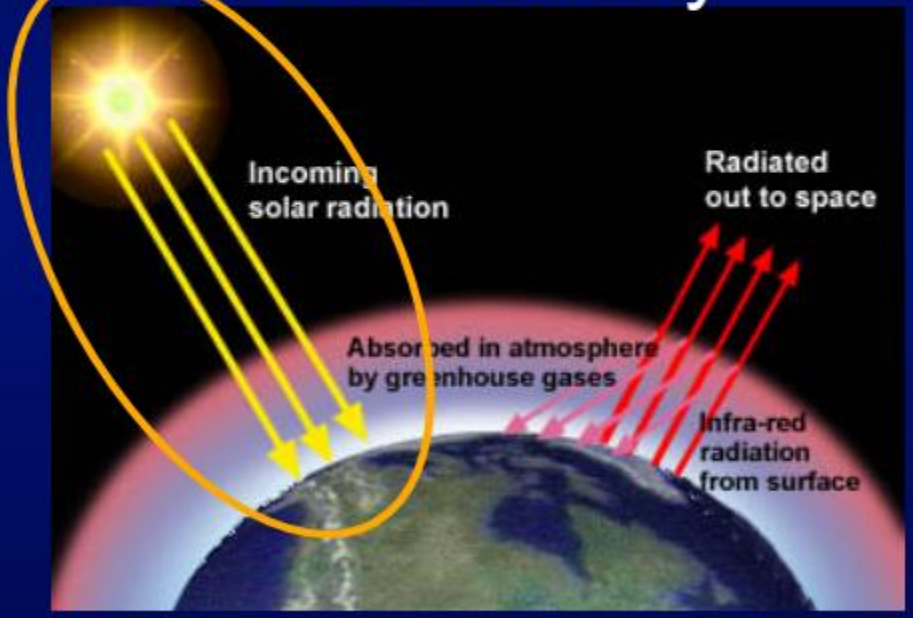
# Regional climate modeling: Why?

- Regional climates are determined by the interactions of planetary/large scale processes and regional/local scale processes
  - Planetary/large scale forcings and circulations determine the statistics of weather events that characterize the climate of a region
  - Regional and local scale forcings and circulations modulate the regional climate change signal, possibly feeding back to the large scale circulations
- In order to simulate climate (and more specifically climate change) at the regional scale it is thus necessary to simulate processes at a wide range of spatial (and temporal) scales

# Large scale natural climatic forcings

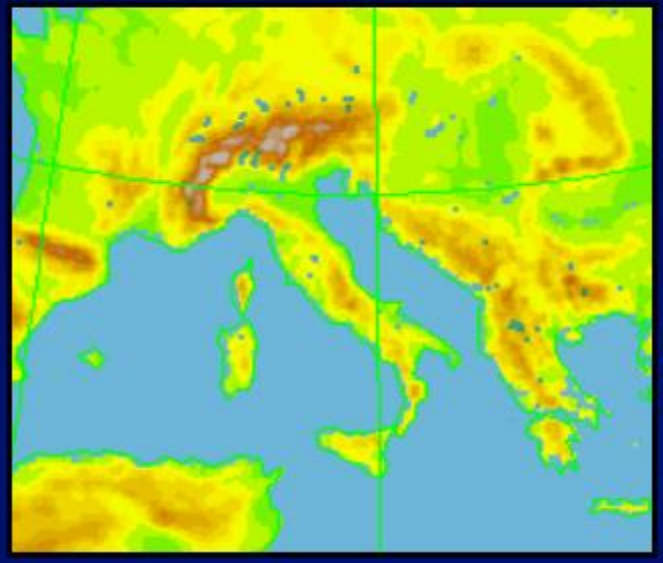
## Volcanic eruptions

## Solar activity

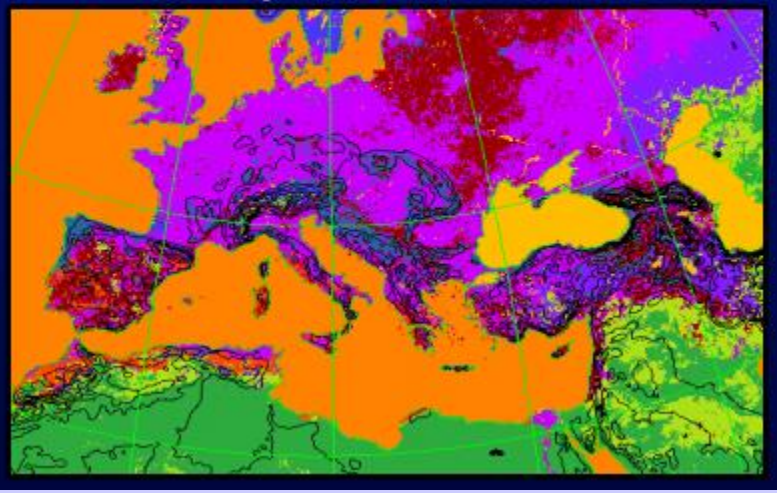


# Regional and local climatic forcings

## Complex topography

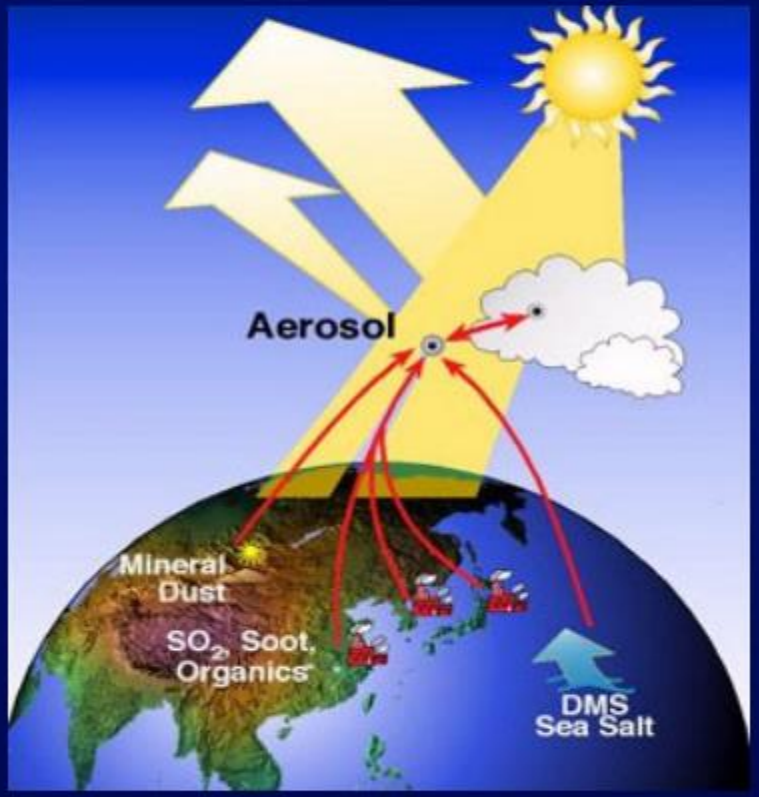


## Complex landuse

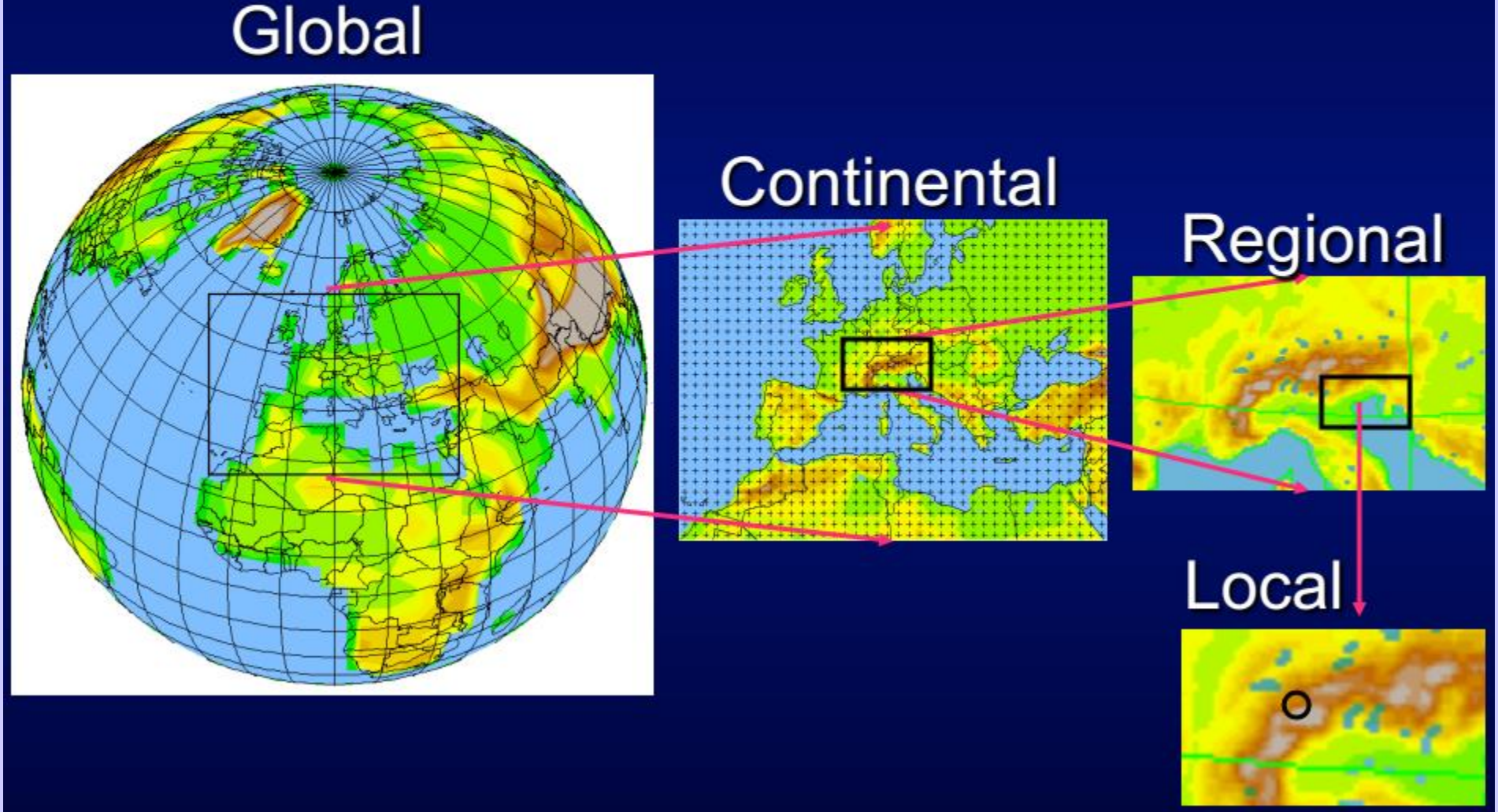


## Aerosols

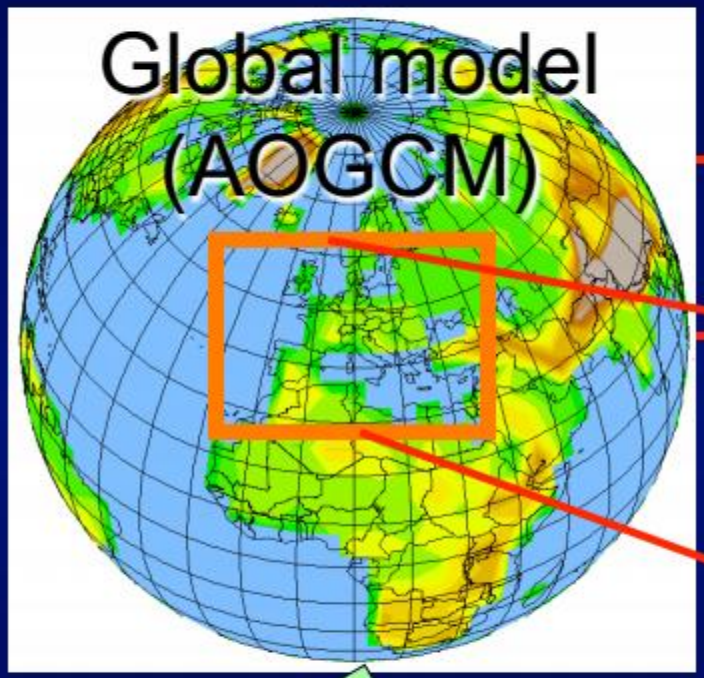
Direct and indirect effects



# Climate change needs to be simulated at multiple spatial scales



# Several tools are available for producing regional climate information




Time-slice
AGCM,
VARGCM

Regional
Model (RCM)

Statistical
Downscaling

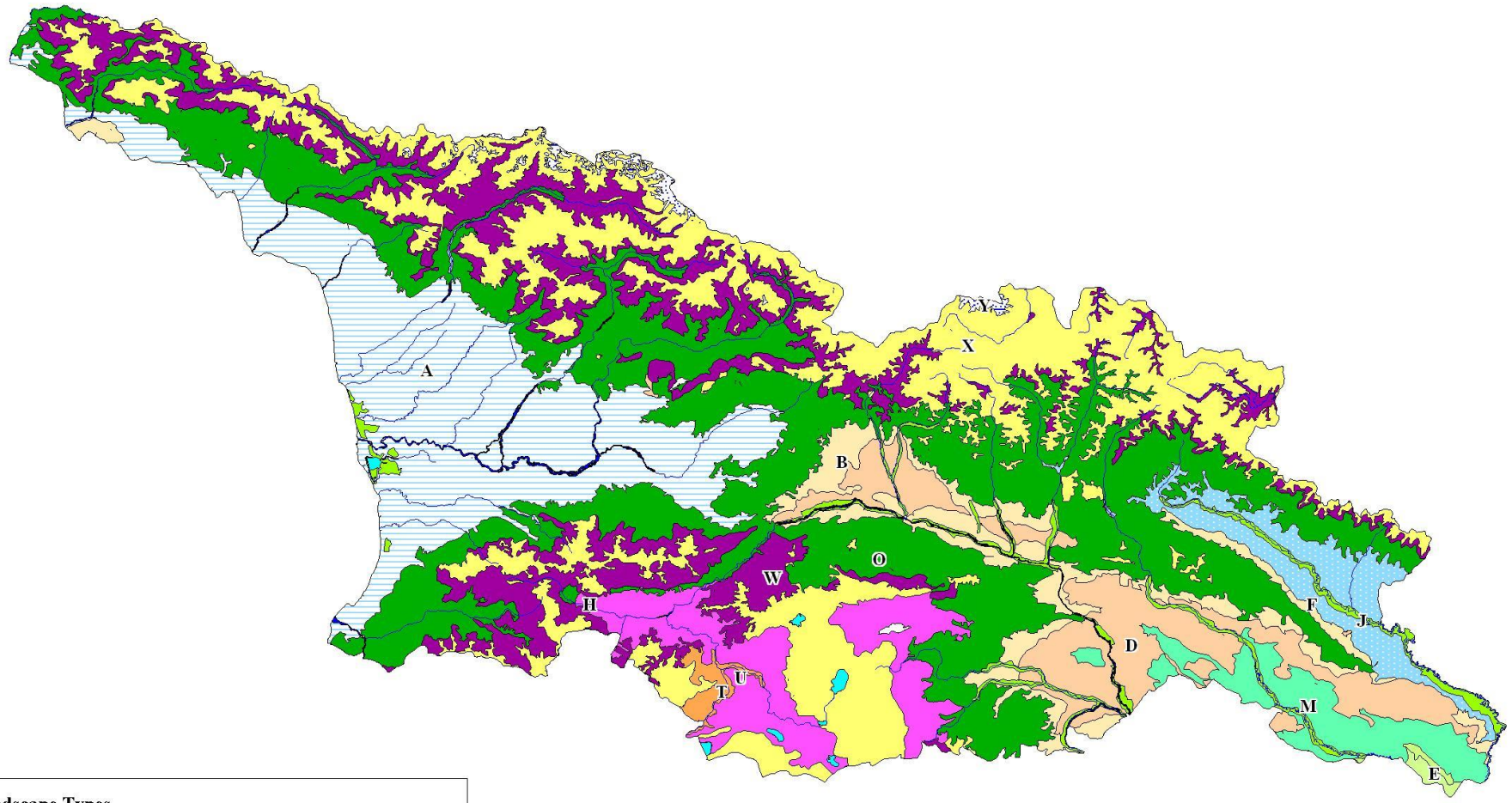
**Impacts**

Storms | Flood | Drought | Water Resources | Energy | Agriculture | Landuse Change | Pollution | Health | Fisheries | Ecosystems

# Regional Climate Model – RegCM4

RegCM was originally developed at the NCAR (National Center for Atmosphere Research) and has been mostly applied to studies of regional climate and seasonal predictability around the world. RegCM is currently maintained the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy. RegCM is a family of limited area models (LAMs) in which large scale meteorological fields from GCM runs provide initial and time-dependent meteorological lateral boundary conditions (LBCs) for high resolution RCM simulations. The RegCM modeling system has four components: Terrain, ICBC, RegCM, and Postprocessor. Terrain and ICBC are the two components of RegCM preprocessor. Terrestrial variables (including elevation, landuse and sea surface temperature) and three-dimensional isobaric meteorological data are horizontally interpolated from a latitude-longitude mesh to a high-resolution domain on either a Rotated (or Normal) Mercator, Lambert Conformal, or Polar Stereographic projection. Vertical interpolation from pressure levels to the $\sigma$ coordinate system of RegCM is also performed. Surfaces near the ground closely follow the terrain, and the higher-level surfaces tend to approximate isobaric surfaces. RegCM uses the radiation scheme of the NCAR CCM3. The optical properties of the cloud droplets (extinction optical depth, single scattering albedo, and asymmetry parameter) are expressed in terms of the cloud liquid water content and an effective droplet radius. The surface physics are performed using Biosphere-Atmosphere Transfer Scheme version 1e (BATS1e).

# Plain and Foothills Landscapes
# Mountainous Landscapes




**Landscape Types**

| | | | |
|---|---|---|---|
| A | F | M | U |
| B | H | N | W |
| D | I | O | X |
| E | J | T | Y |

A

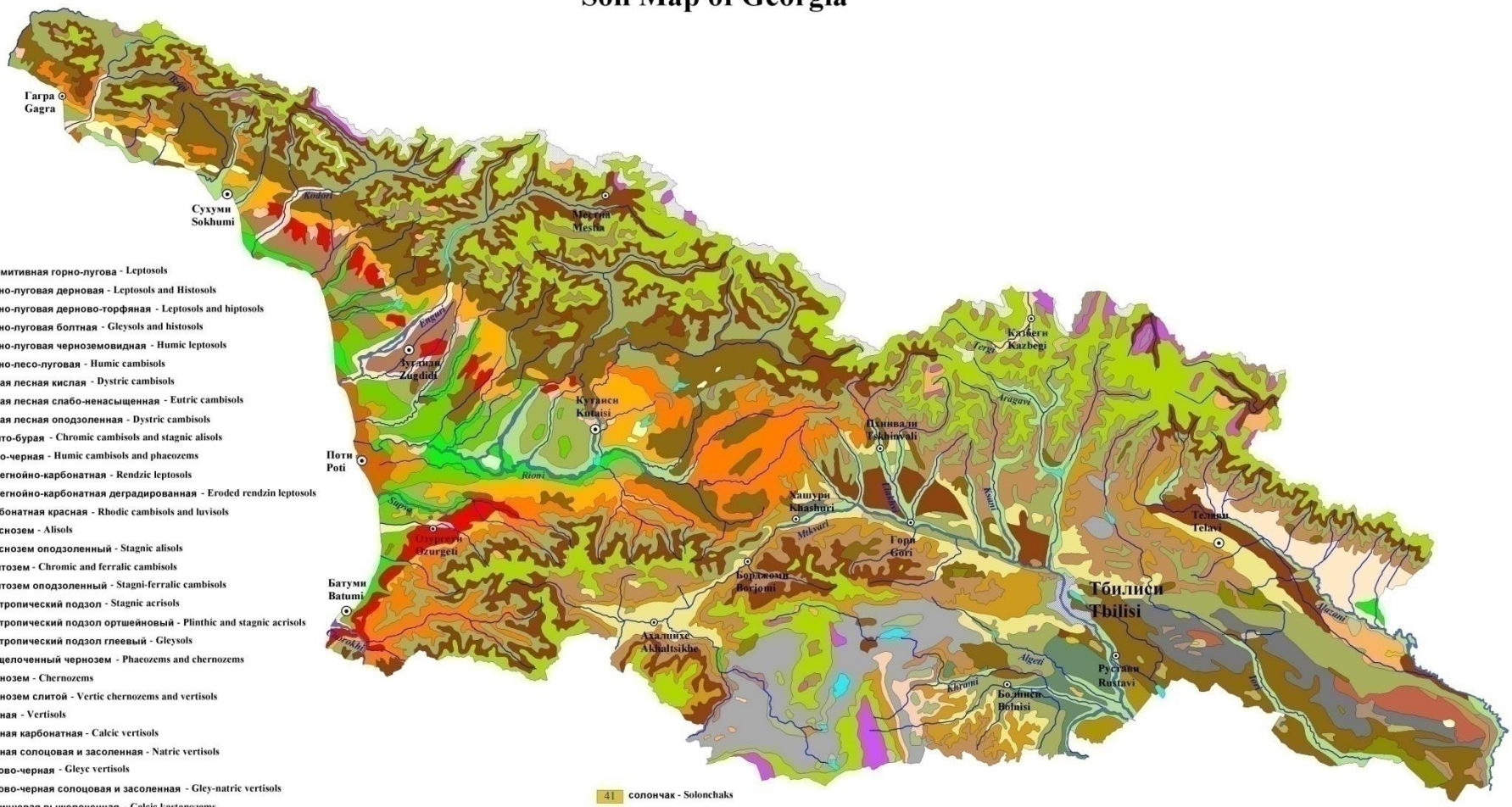
B

C

D

**A** - A clear example of anthropogenic stress (Intensive sheep breeding) and Global warming (Desertification). Dedoplistkaro research area. **B** - Gergeti glacier at the slopes of mount Kazbegi 5033 m., Stefantsminda research area. **C** - Rare survivals of high mountain forests in Javakheti highland at about 1900 m above sea level. **D** - Kolkheti wetland, marshes. Black Sea shore research area.

# Почвенная Карта Грузии
# Soil Map of Georgia




1 примитивная горно-лугова - Leptosols
2 горно-луговая дерновая - Leptosols and Histosols
3 горно-луговая дерново-торфяная - Leptosols and hiptosols
4 горно-луговая болтная - Gleysols and histosols
5 горно-луговая черноземовидная - Humic leptosols
6 горно-лесо-луговая - Humic cambisols
7 бурая лесная кислая - Dystric cambisols
8 бурая лесная слабо-ненасыщенная - Eutric cambisols
9 бурая лесная оподзоленная - Dystric cambisols
10 желто-бурая - Chromic cambisols and stagnic alisols
11 буро-черная - Humic cambisols and phaeozems
12 перегнойно-карбонатная - Rendzic leptosols
13 перегнойно-карбонатная деградированная - Eroded rendzin leptosols
14 карбонатная красная - Rhodic cambisols and luvisols
15 краснозем - Alisols
16 краснозем оподзоленный - Stagnic alisols
17 желтозем - Chromic and ferralic cambisols
18 желтозем оподзоленный - Stagni-ferralic cambisols
19 субтропический подзол - Stagnic acrisols
20 субтропический подзол ортшейновый - Plinthic and stagnic acrisols
21 субтропический подзол глеевый - Gleysols
22 выщелоченный чернозем - Phaeozems and chernozems
23 чернозем - Chernozems
24 чернозем слитой - Vertic chernozems and vertisols
25 черная - Vertisols
26 черная карбонатная - Calcic vertisols
27 черная солоцовая и засоленная - Natric vertisols
28 лугово-черная - Gleyc vertisols
29 лугово-черная солоцовая и засоленная - Gley-natric vertisols
30 коричневая выщелоченная - Calcic kastanozems
31 коричневая - Eutric cambisols and calcic kastanozems
32 коричневая карбонатная - Calcaric cambisols and calcic kastanozems
33 коричневая светлая - Calcic kastanozems
34 лугово- коричневая - Calcaric cambisols and calcic kastanozems
35 лугово-серо- коричневая - Calcic vertisols
36 серо- коричневая темная - Calcic kastanozems
37 серо- коричневая - Calcic kastanozems
38 серо- коричневая светлая - Calcic kastanozems
39 перегнойно-сульфатная - Gypsisols
40 солонец - Solonetz

41 солончак - Solonchaks
42 аппювиальная кислая - Dyctric fluvisols
43 аппювиальная насыщенная - Eutric fluvisols
44 аппювиальная карбонатная - Calcaric fluvisols
45 иловато-болотная - Gleysols
46 торфяно- болотная - Histosols
47 антропогенные почвы - Anthric regosols and anthrsols
48 сыльно смытые почвы и обноженя пород - Rock outcrops and leptosols
49 ледники - Glaciers

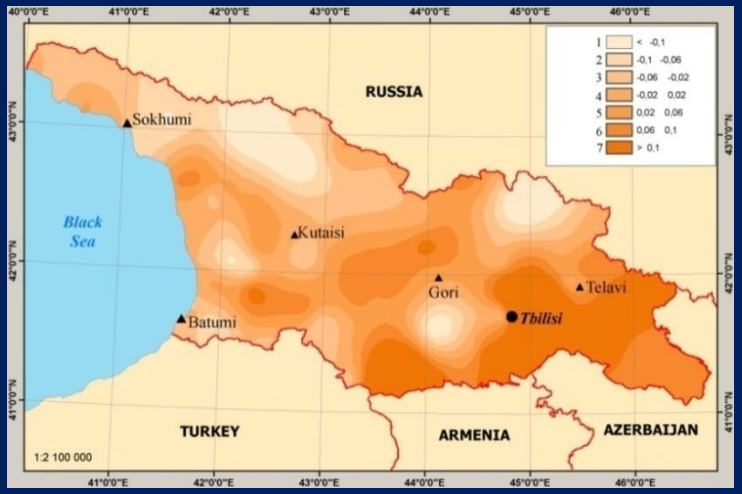
Озера и водохранилища
Lakes and reservoirs
Реки и каналы
Rivers and canals
Населенные пункты
Populated areas

Масштаб 1 : 1 000 000
Scale 1 : 1 000 000

T.Urushadze etc.

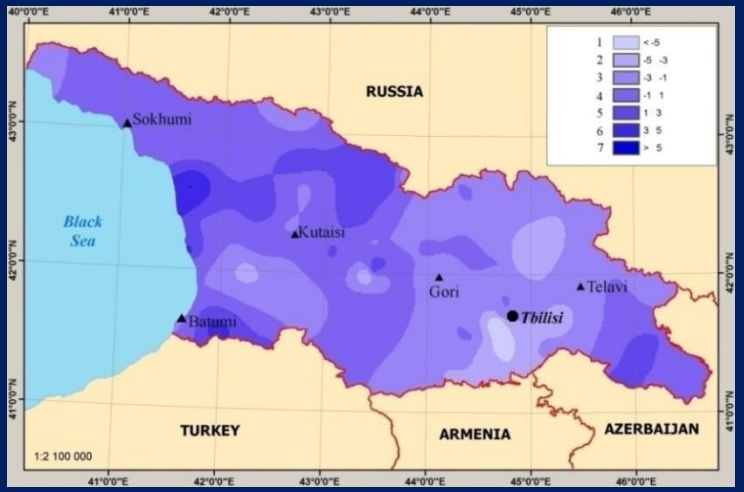
**Development and validation of 1936-2008 year high resolution monthly gridded temperature and precipitation data set for use in global climate change assessment for Georgia. 2010-2012, Shota Rustaveli National Science Foundation**


Velocity of annual mean air temperature change ºC in decade




Velocity of January mean air temperature change ºC in decade


Velocity of July mean air temperature change ºC in decade




Precipitation annual sum variation velocity % in decade

# The equations of a climate model

$$\frac{\partial \overline{V}}{\partial t} + \overline{V} \cdot \nabla \overline{V} = -\frac{\nabla p}{\rho} - 2\overline{\Omega} \times \overline{V} + \overline{g} + \overline{F}_{\overline{V}}$$

Conservation of momentum

$$C_p\left(\frac{\partial T}{\partial t} + \overline{V} \cdot \nabla T\right) = \frac{1}{\rho}\frac{dp}{dt} + Q + F_T$$

Conservation of energy

$$\frac{\partial \rho}{\partial t} + \overline{V} \cdot \nabla \rho = -\rho \nabla \cdot \overline{V}$$

Conservation of mass

$$\frac{\partial q}{\partial t} + \overline{V} \cdot \nabla q = \frac{S_q}{\rho} + F_q$$

Conservation of water

$$p = \rho R T$$

Equation of state

# Regional Climate Modeling Issues
## Model physics

- Should the physics schemes in the nested RCM and driving GCM be the same?
  - Same physics would lead to a better interpretation of model results
  - Same physics would maximize consistency between LBC and RCM
  - GCM physics (e.g. convection) may not be suitable for fine scales. Each model uses schemes developed for their respective resolutions
  - A given scheme may behave very differently at different resolutions
- Simulations of comparable quality have been conducted with RCMs having wither the same or different physics schemes from the driving GCM (PRUDENCE)

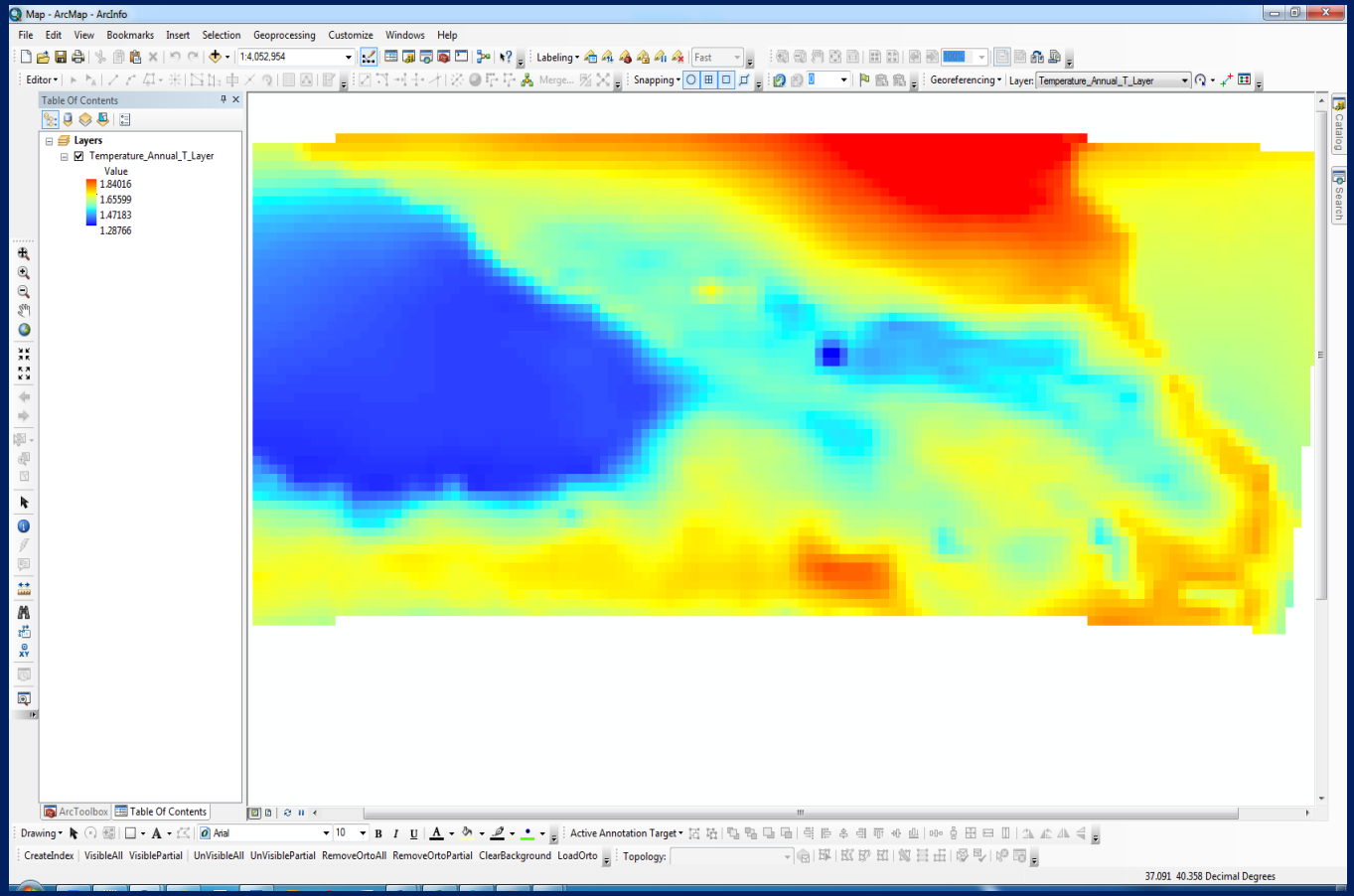
# RegCM4 for South Caucasus region

- The simulation was done from 1959 to 2100 inclusively. The 1961 -1990 period was taken as the baseline, compared to which current and future climate parameters and extreme events were evaluated. Out of 180 different parameters, available as a result of modeling, we analyzed the below-listed climate parameters. Future scenarios were developed for the periods: 2021-2050 and 2071-2100.
- Model was validated and tuned against observations gridded and point ones;
- Monthly temperature and precipitation bias correction was done with CRU data

The following climate parameters were studied to assess climate change in Georgian municipalities:

1. Average annual and seasonal air temperatures ($^0$C);
2. Total annual and seasonal atmospheric precipitation (mm);
3. Absolute maximum and minimum air temperatures ($^0$C);
4. Evaporation (mm);
5. Height of snow cover (cm);
6. Average annual Number of snow days;
7. Average annual Number of heavy rains;
8. Average annual Number of frost days;
9. Average annual Number of hot days;
10. Duration of heating/cooling periods.

# RegCM output files in GIS



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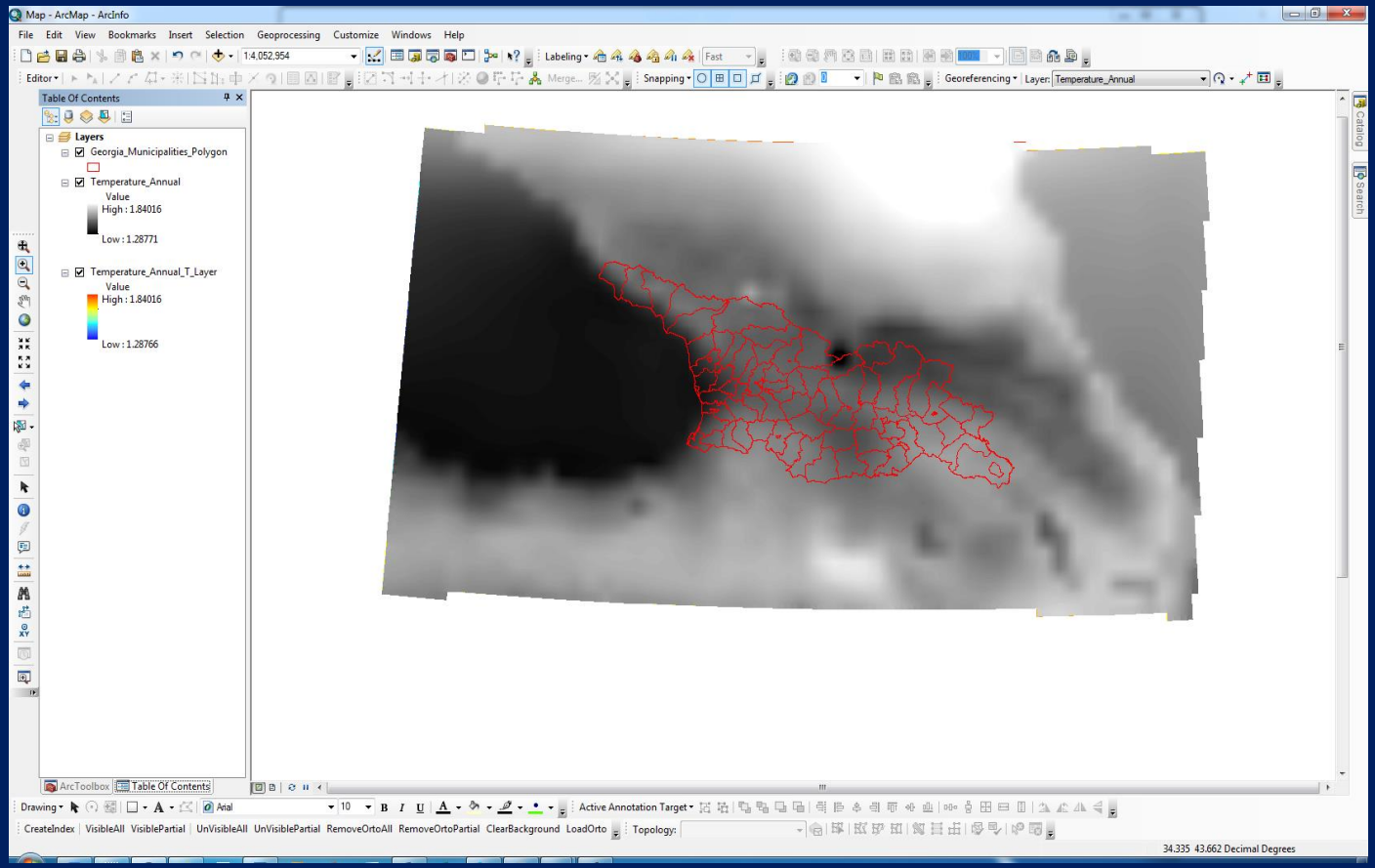
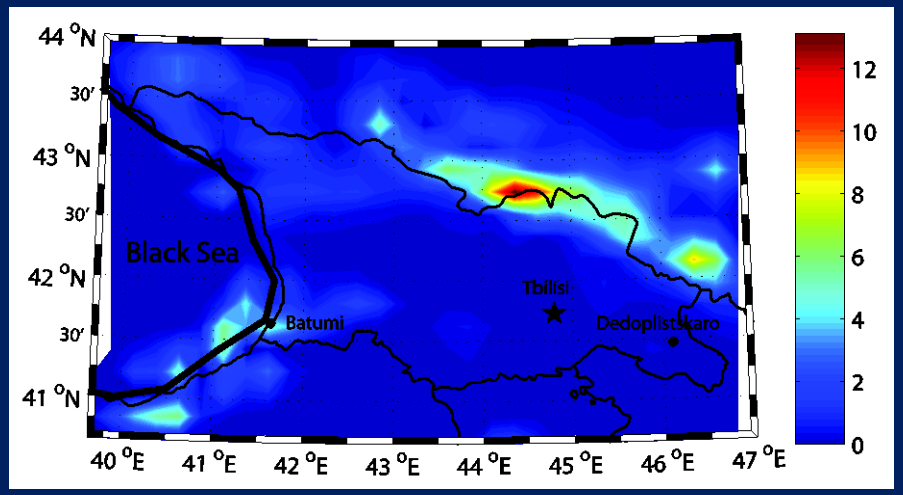
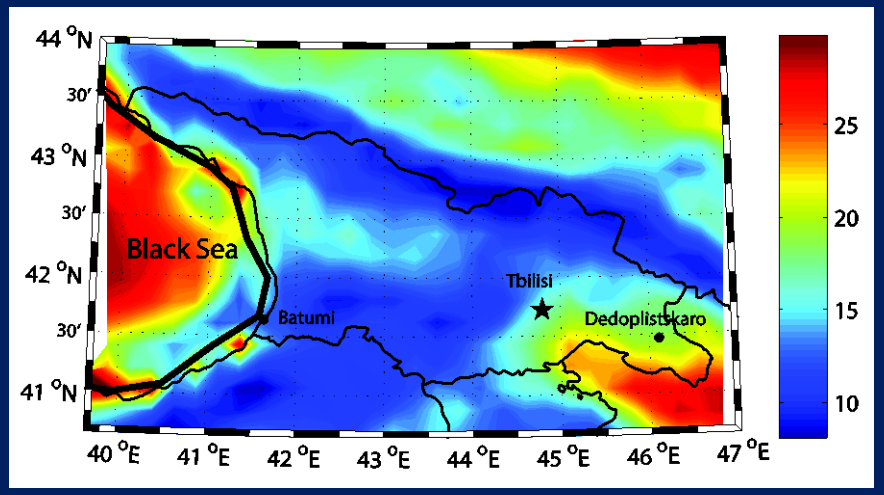


# Extreme Precipitation Indices



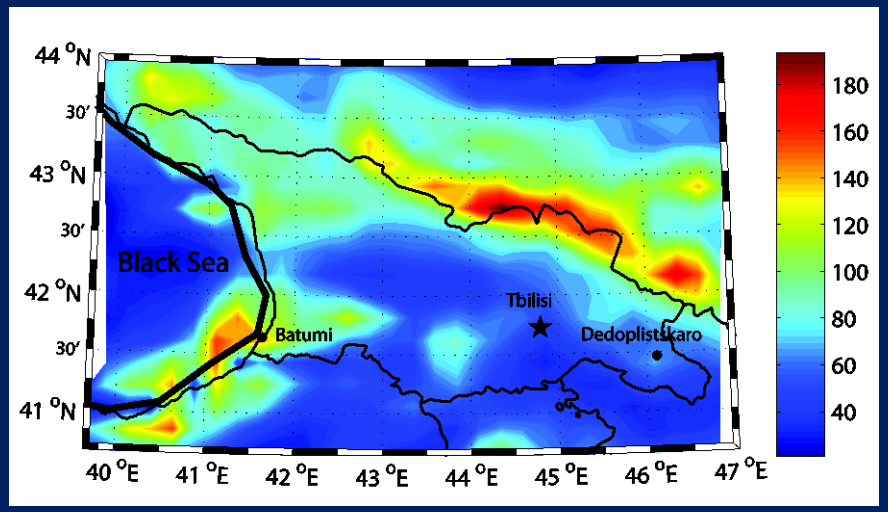

**Average number of PN80 from 1989-2008.**

*PN80 - Number of days with precipitation above 80 mm intensity*



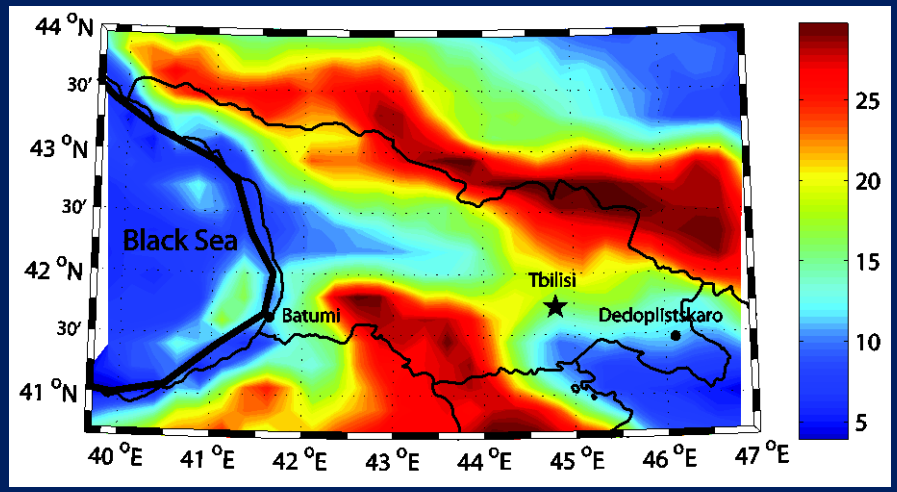

**Average number of MDRY from 1989-2008.**

*MDRY - Maximum duration of consecutive dry days*



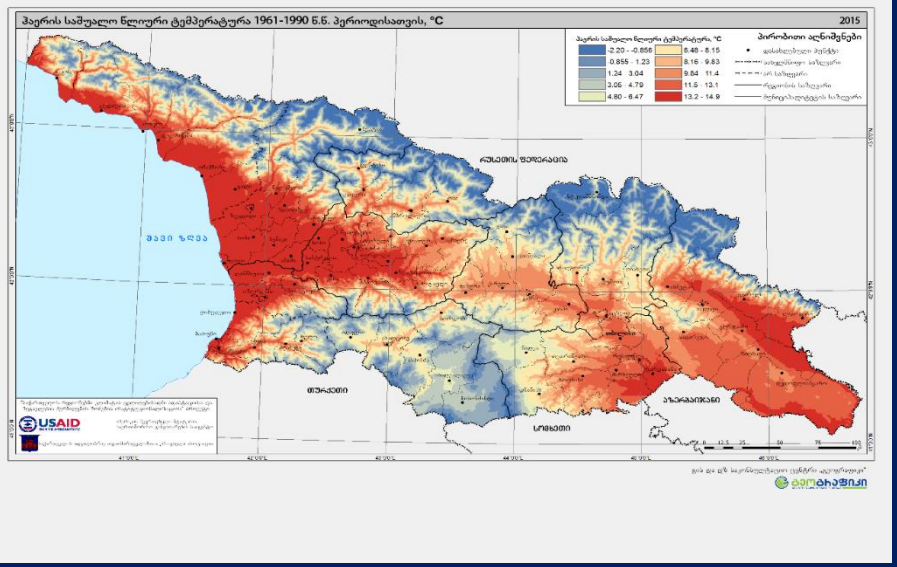

**Average PX1D from 1989-2008 .**

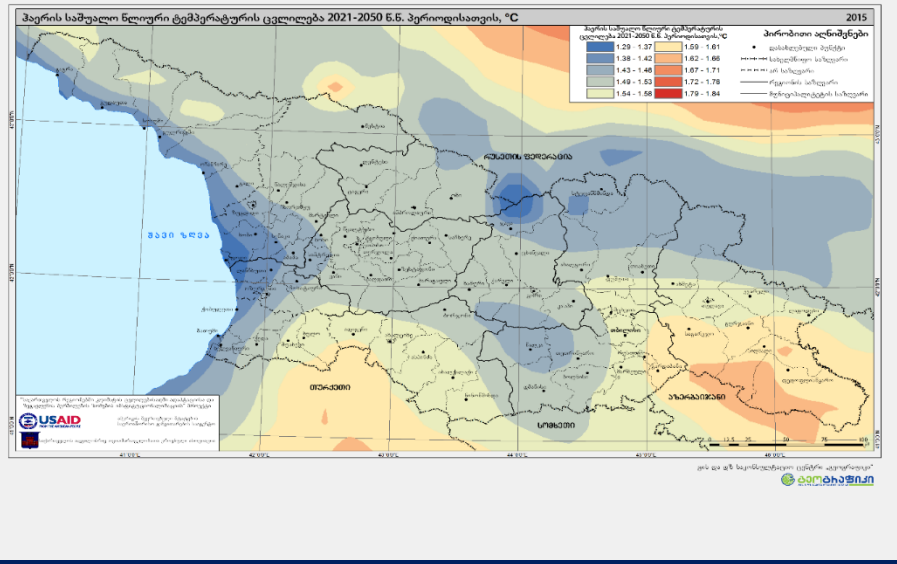
*Greatest 1-day total precipitation.*




**Average number of MWET from 1989-2008**

*MWET - Maximum duration of consecutive wet days*


ჰაერის საშუალო წლიური ტემპერატურა 1961-1990 წ.წ. პერიოდისათვის, °C
2015
ჰაერის საშუალო წლიური ტემპერატურა, °C
-2.20 - -0.856
0.855 - 1.23
1.24 - 3.04
3.05 - 4.79
4.80 - 6.47
6.48 - 8.15
8.16 - 9.83
9.84 - 11.4
11.5 - 13.1
13.2 - 14.9
პირობითი აღნიშვნები
დასახლებული პუნქტი
საერთაშორისო საზღვარი
ავტონომიური საზღვარი
რეგიონის საზღვარი
მუნიციპალიტეტის საზღვარი
რუსეთის ფედერაცია
შავი ზღვა
თურქეთი
სომხეთი
აზერბაიჯანი


ჰაერის საშუალო წლიური ტემპერატურის ცვლილება 2021-2050 წ.წ. პერიოდისათვის, °C
2015
ჰაერის საშუალო წლიური ტემპერატურის ცვლილება 2021-2050 წ.წ. პერიოდისათვის,°C
1.29 - 1.37
1.38 - 1.42
1.43 - 1.48
1.49 - 1.53
1.54 - 1.58
1.59 - 1.61
1.62 - 1.66
1.67 - 1.71
1.72 - 1.78
1.79 - 1.84
პირობითი აღნიშვნები
დასახლებული პუნქტი
საერთაშორისო საზღვარი
ავტონომიური საზღვარი
რეგიონის საზღვარი
მუნიციპალიტეტის საზღვარი
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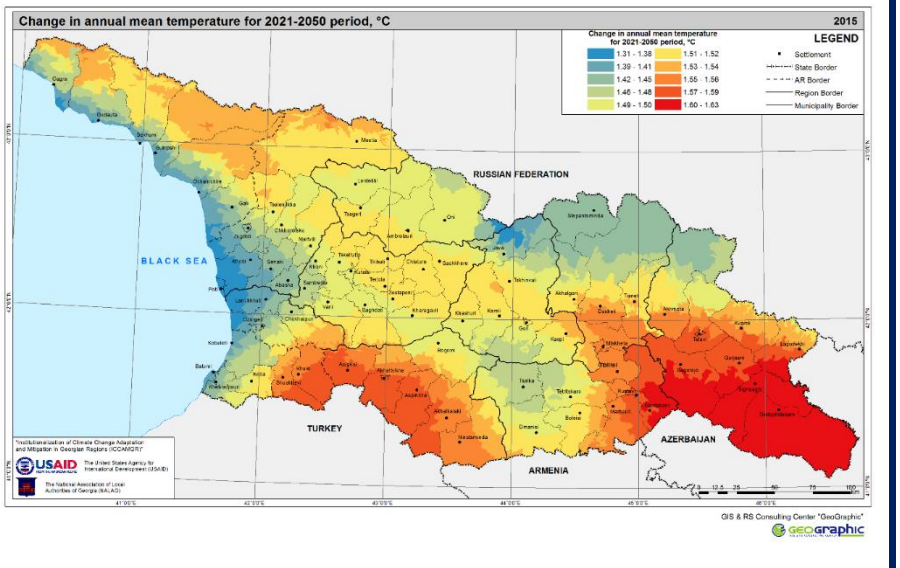
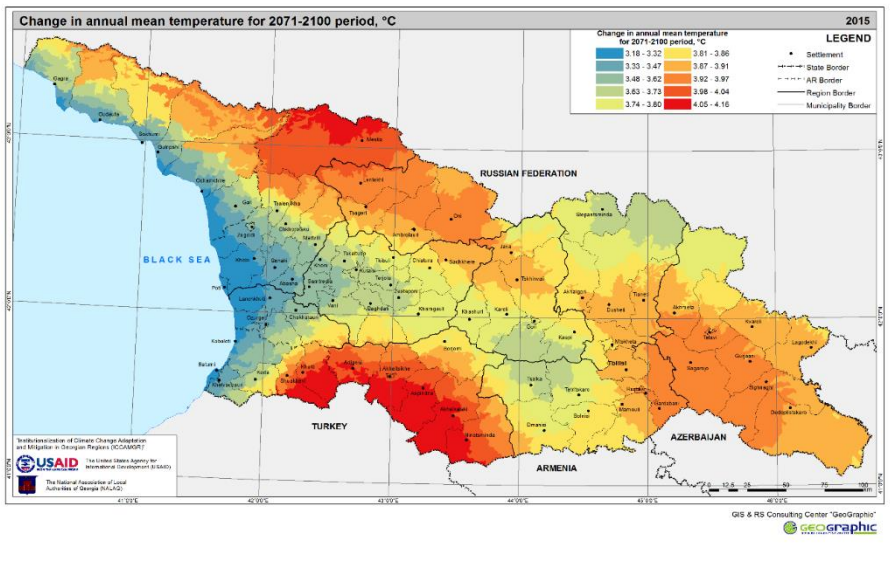
სომხეთი
აზერბაიჯანი


Change in annual mean temperature for 2021-2050 period, °C
2015
Change in annual mean temperature for 2021-2050 period, °C
1.31 - 1.38
1.39 - 1.41
1.42 - 1.45
1.46 - 1.48
1.49 - 1.50
1.51 - 1.52
1.53 - 1.54
1.55 - 1.56
1.57 - 1.59
1.60 - 1.63
LEGEND
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
ARMENIA
AZERBAIJAN
GIS & RS Consulting Center "GeoGraphic"


Change in annual mean temperature for 2071-2100 period, °C
2015
Change in annual mean temperature for 2071-2100 period, °C
3.18 - 3.32
3.33 - 3.47
3.48 - 3.62
3.63 - 3.73
3.74 - 3.80
3.81 - 3.86
3.87 - 3.91
3.92 - 3.97
3.98 - 4.04
4.05 - 4.16
LEGEND
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
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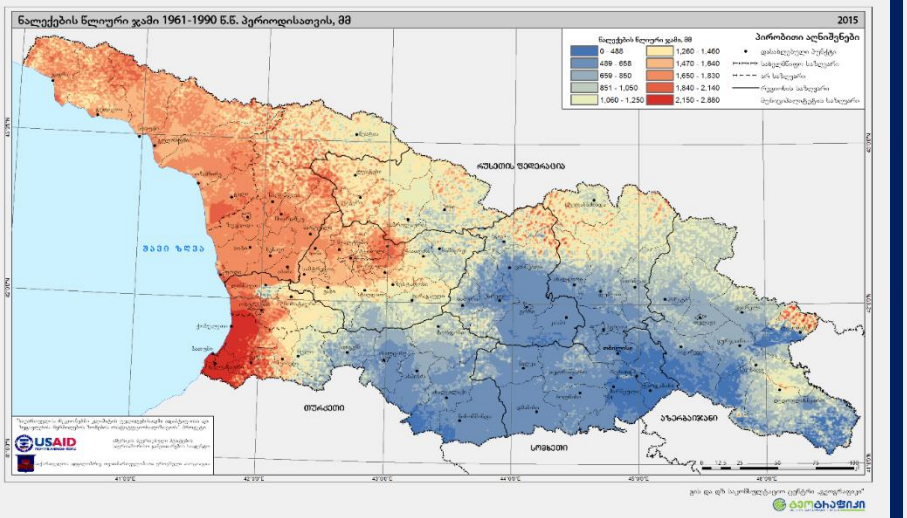
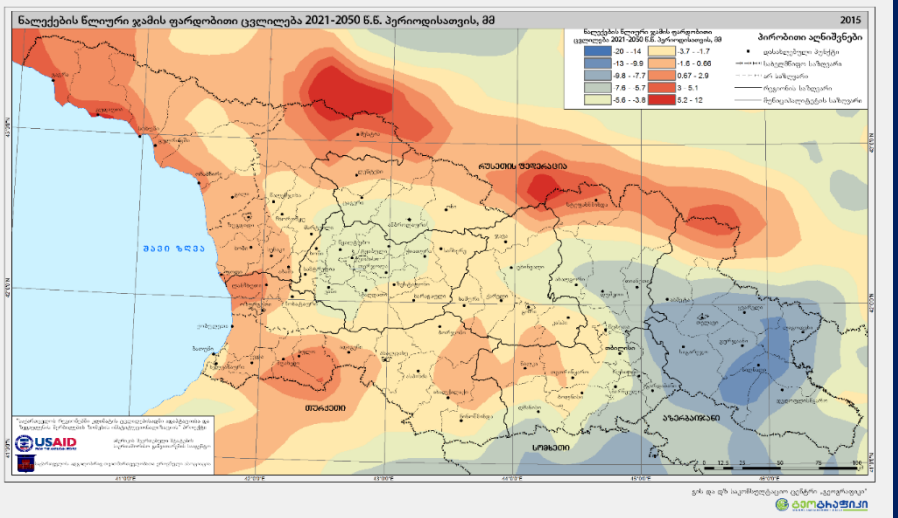

ნალექების წლიური ჯამი 1961-1990 წ.წ. პერიოდისათვის, მმ
2015
პირობითი აღნიშვნები
რუსეთის ფედერაცია
შავი ზღვა
თურქეთი
სომხეთი
აზერბაიჯანი


ნალექების წლიური ჯამის ფარდობითი ცვლილება 2021-2050 წ.წ. პერიოდისათვის, მმ
2015
პირობითი აღნიშვნები
რუსეთის ფედერაცია
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თურქეთი
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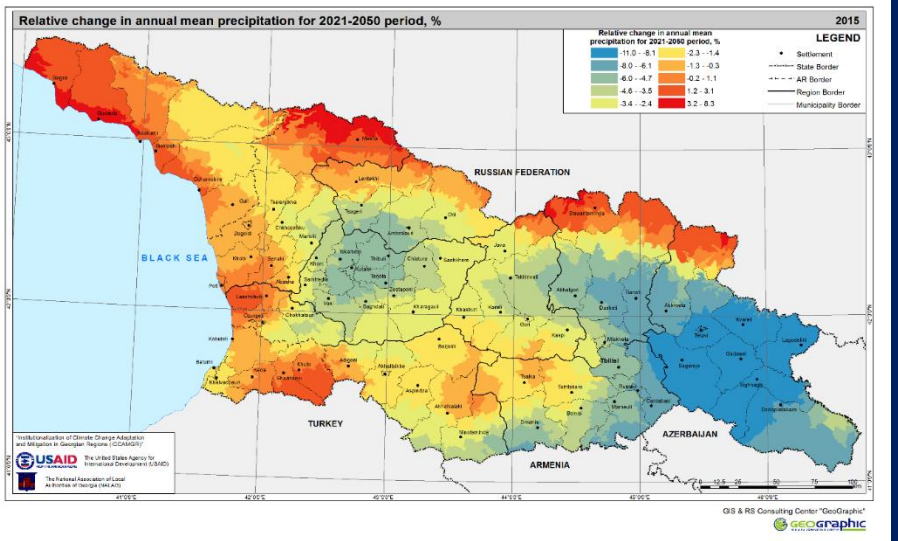
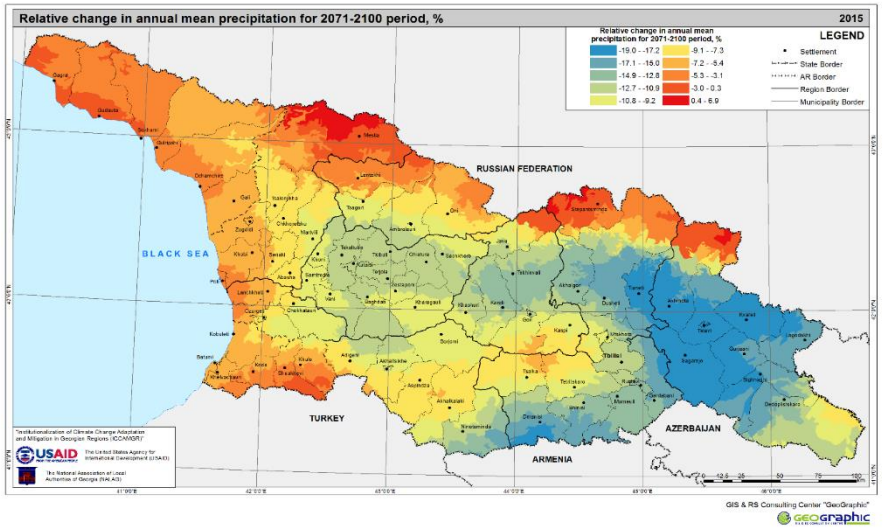

Relative change in annual mean precipitation for 2021-2050 period, %
2015
LEGEND
RUSSIAN FEDERATION
BLACK SEA
TURKEY
ARMENIA
AZERBAIJAN


Relative change in annual mean precipitation for 2071-2100 period, %
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RUSSIAN FEDERATION
BLACK SEA
TURKEY
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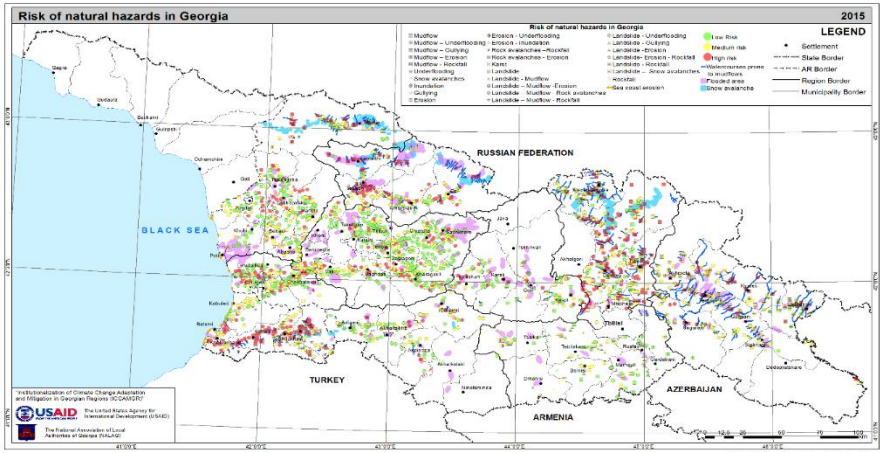
AZERBAIJAN


Risk of natural hazards in Georgia
2015
LEGEND
Risk of natural hazards in Georgia
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
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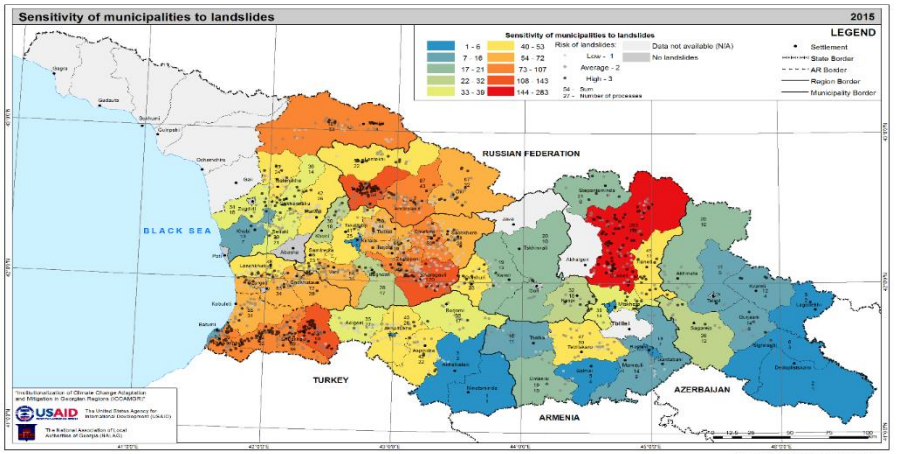
Sensitivity of municipalities to landslides
2015
LEGEND
Sensitivity of municipalities to landslides
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
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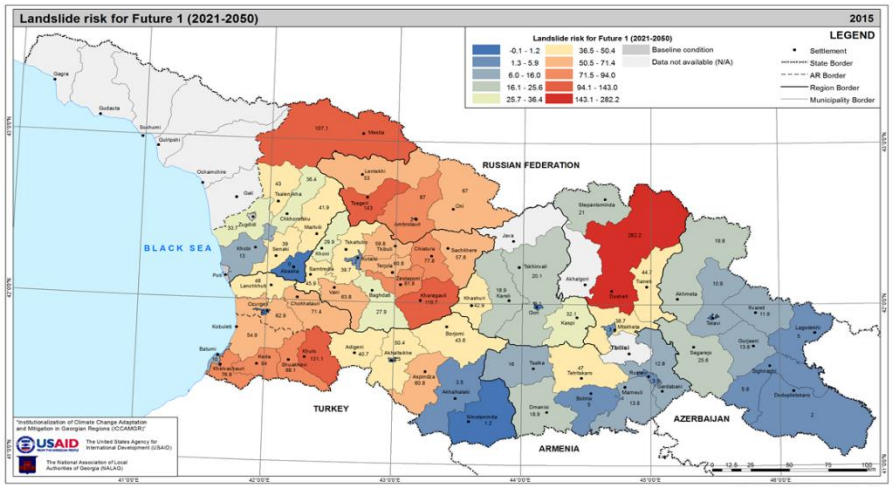
Landslide risk for Future 1 (2021-2050)
2015
LEGEND
Landslide risk for Future 1 (2021-2050)
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
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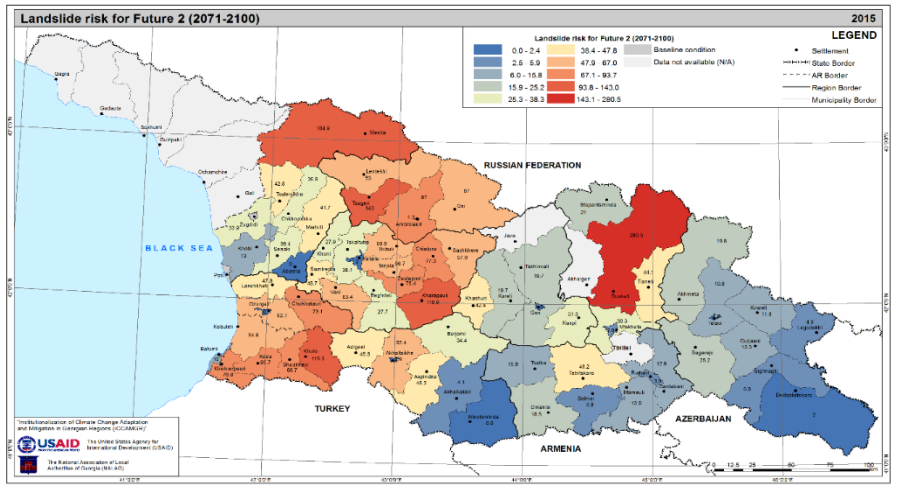
Landslide risk for Future 2 (2071-2100)
2015
LEGEND
Landslide risk for Future 2 (2071-2100)
Settlement
State Border
AR Border
Region Border
Municipality Border
RUSSIAN FEDERATION
BLACK SEA
TURKEY
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Thank you