8th GEWEX Open Science Conference: Extremes and Water on the Edge, 6-11 May 2018, Canmore, Alberta, Canada

Modeling the Land Use and Land Cover Changes in the Euphrates & Tigris Basin:

How Does It Affect the Regional Water Budget and Energy Balance Under a Changing Climate?

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Harran Plain, Turkey

Image source : Sentinel-2 - 2016

10 km

Motivation

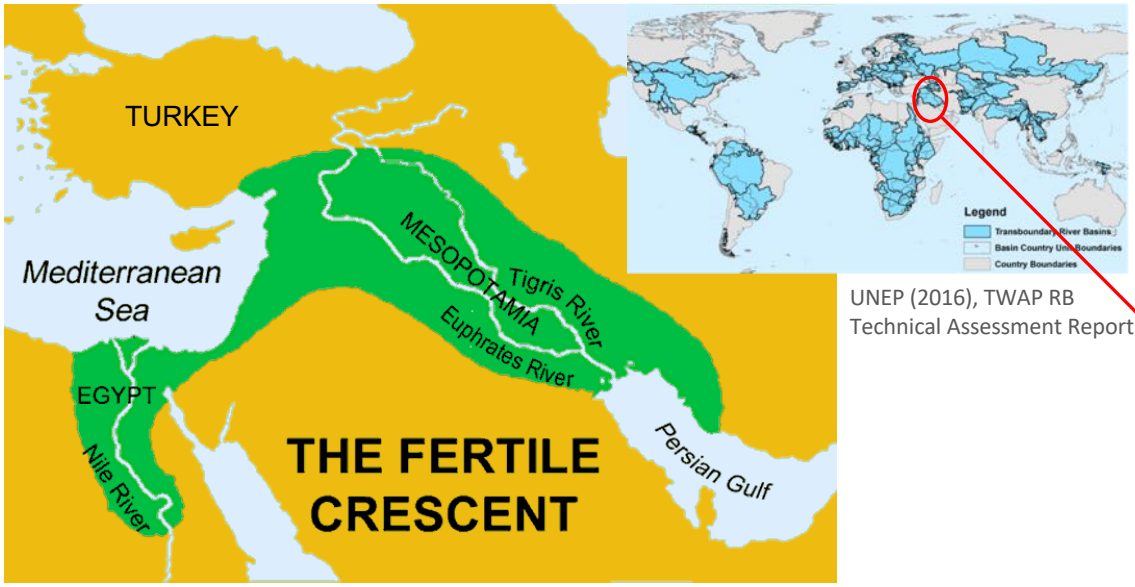
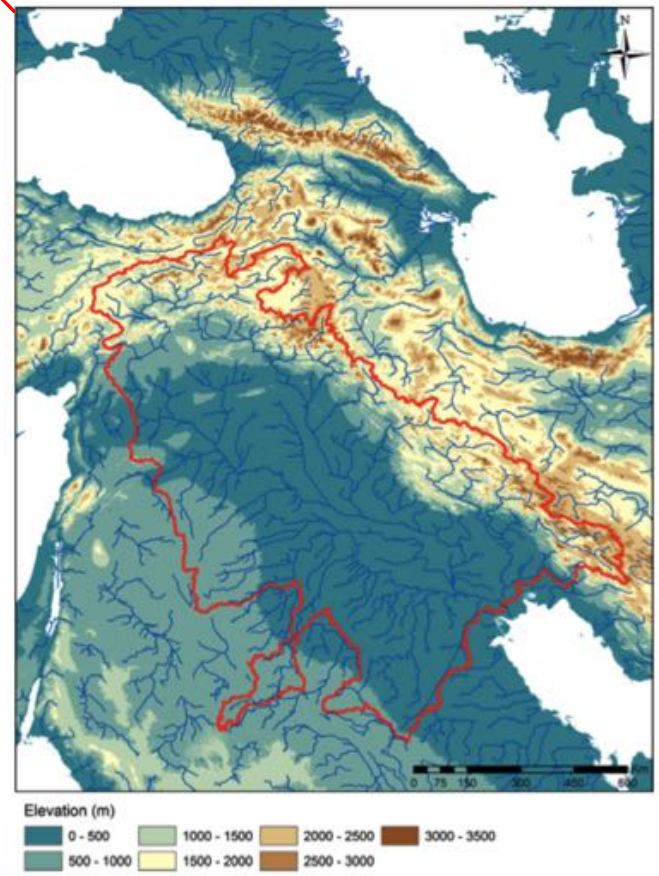


image source: Dowling, Mike.

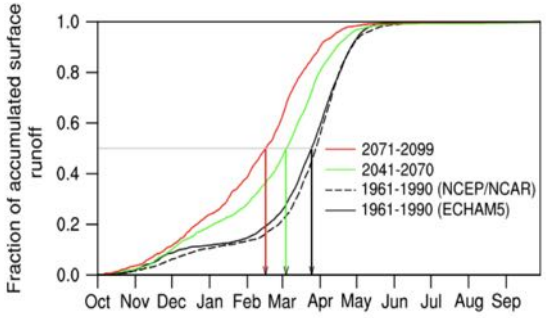
UNEP (2016), TWAP RB Technical Assessment Report

Euphrates & Tigris Basin (ETB)

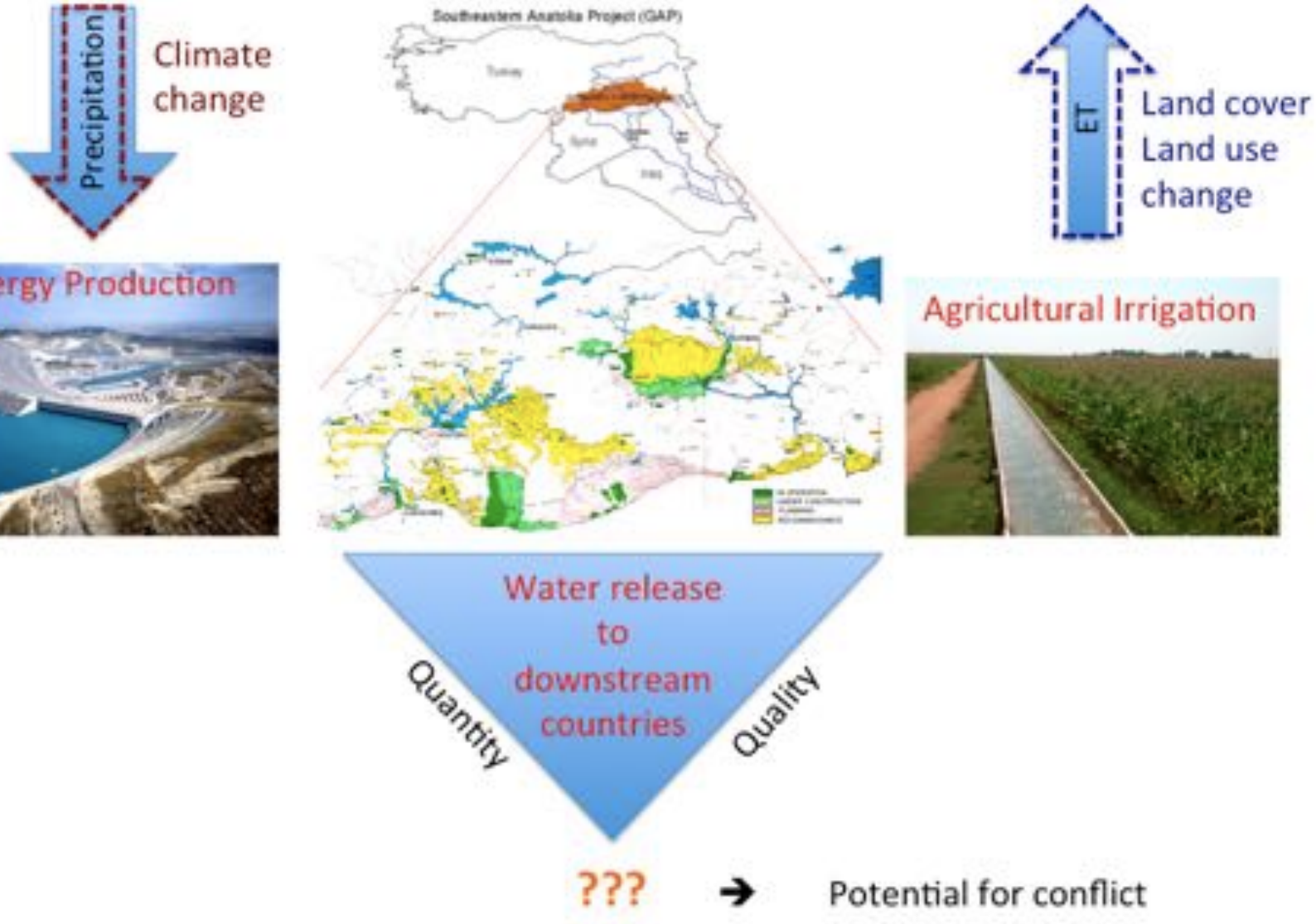
Bozkurt and Sen, J. of Hydrol.,2013



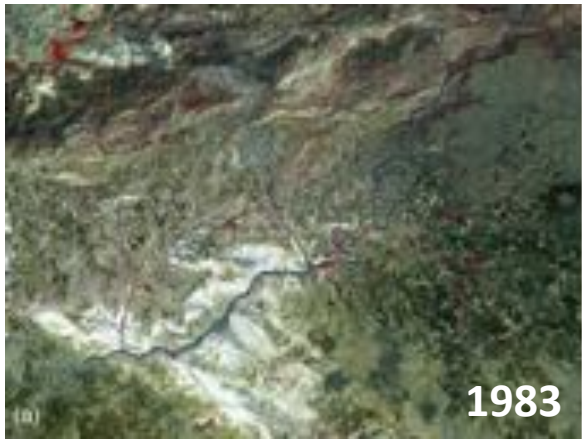
- Snow-fed transboundary river basin
- Future simulations
  - Precipitation decrease in headwaters region
  - Projected peak streamflow occurs earlier in the year
- **Southeastern Anatolia Project**
  - Irrigated cultivation



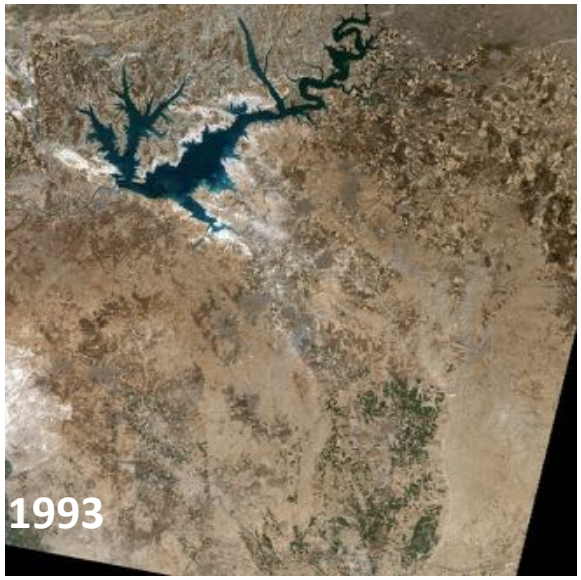
Southeastern Anatolia Project (GAP)



Southeastern Anatolia Project (GAP)



Landsat images show the area before (a) and after (b) the Ataturk Dam was built.
https://visibleearth.nasa.gov/view.php?id=3796



Extension of the irrigated areas in the Harran Plains.
https://earthobservatory.nasa.gov/Features/HarranPlains/

- **Irrigated Area**
  - **2016**
    502,154 ha
  - **Future**
    1.8 million ha
    22 dams
    19 HPP

Objectives

- To reveal the **effect of LULC changes** on the current climate and water resources of the region
- To calculate the **water loss** via evapotranspiration due to the extension of irrigated cultivation
- To evaluate how LULC changes affect the **regional water budget** under a changing climate

Method

?

- Dynamical downscaling (regional climate model)
  - **RegCM4** (revision 4283)

The Abdus Salam International Centre for Theoretical Physics

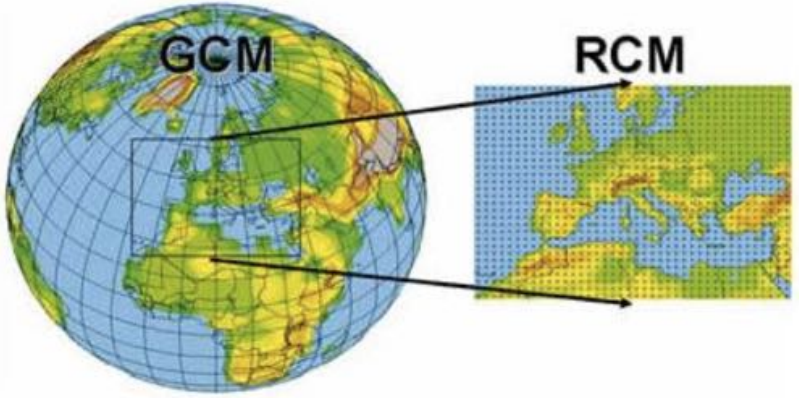


image source : F. Giorgi, WMO Bulletin 57(2), 2008

GCM	Model Name	Modeling Center (or Group)	Resolution (lat,lon)
1	BCC CSM1	Beijing Climate Center, China Meteorological Administration	2.8x2.8
2	BCC CSM 1M		1.1x1.1
3	BNU ESM	College of Global Change and Earth System Science, Beijing Normal University	2.8x2.8
4	CCCMA CM4	Canadian Centre for Climate Modelling and Analysis	2.8x2.8
5	CCCMA ESM2		2.8x2.8
6	CCSR ESM	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	2.8x2.8
7	CCSR ESM CHEM		2.8x2.8
8	CCSR MIROC4H		0.56x0.56
9	CCSR MIROC5		1.4x1.4
10	CMCC CM	Centro Euro-Mediterraneo per I Cambiamenti Climatici	0.75x0.75
11	CMCC CMS		1.8x1.8
12	CNRM CM5	Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique	1.4x1.4
13	CSIRO AC10	Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	1.25x1.8
14	CSIRO AC13		1.25x1.8
15	CSIRO MK6		1.8x1.8
16	ECMWF EC EARTH	EC-EARTH consortium	1.1x1.1
17	FIO ESM	The First Institute of Oceanography, SOA, China	2.8x2.8
18	GFDL CM3	NOAA Geophysical Fluid Dynamics Laboratory	2x2.5
19	GFDL ESM2G		2x2.5
20	GFDL ESM2M		2x2.5
21	GISS E2H	NASA Goddard Institute for Space Studies	2x2.5
22	GISS E2H-CC		2x2.5
23	GISS E2R		2x2.5
24	GISS E2R-CC		2x2.5
25	INM CM4	Institute for Numerical Mathematics	1.5x2
26	IPSL CM5ALR	Institut Pierre-Simon Laplace	1.9x3.75
27	IPSL CM5AMR		1.25x2.5
28	IPSL CM5BLR		1.9x3.75
29	LASG FGOALSG2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences and CESS, Tsinghua	2.8x2.8
30	LASG FGOALSS2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	1.6x2.8
31	MPI ESMLR	Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)	1.9x1.9
32	MPI ESMMR		1.9x1.9
33	MPI ESMP		1.9x1.9
34	MRI CGCM3	Meteorological Research Institute	1.1x1.1
35	NCAR CCSM4	National Center for Atmospheric Research	0.9x1.25
36	NCAR CESM1-BGC	Community Earth System Model Contributors	0.9x1.25
37	NCAR CESM1-CAM5		0.9x1.25
38	NCAR CESM1-FCHEM		0.9x1.25
39	NCAR CESM1-WACCM		1.9x2.5
40	NOR ESM1M	Norwegian Climate Centre	1.9x2.5
41	NOR ESM1ME		1.9x2.5
42	UKMO HADCM3	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	2.5x3.75
43	UKMO HADGEM2AO		1.25x1.875
44	UKMO HADGEM2CC		1.25x1.875
45	UKMO HADGEM2ES		1.25x1.875
46	MME GCM	Multi Model Ensemble	0.5x0.5

Observation :

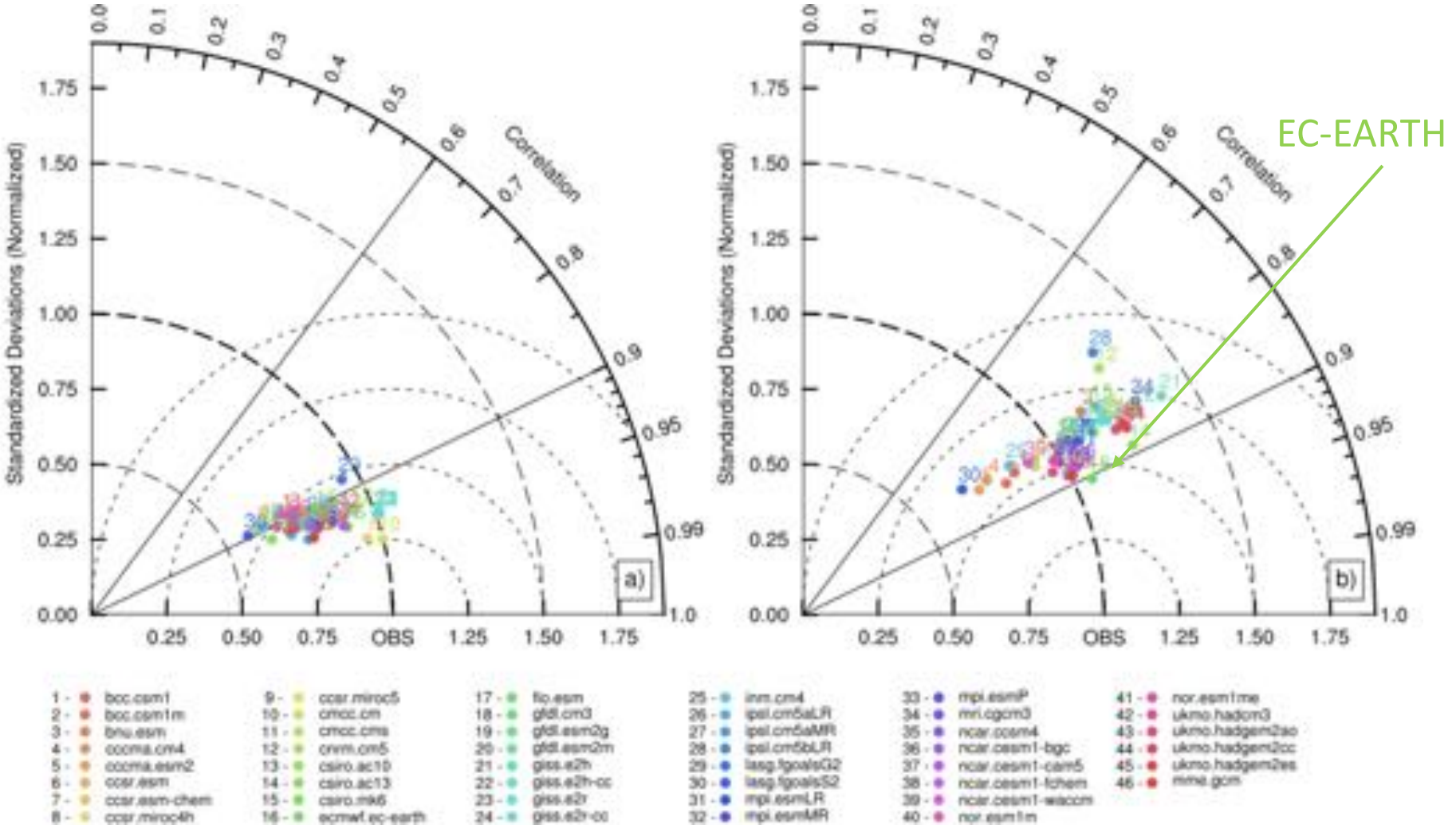
CRU (Climate Research Unit) TS v 4.01 (0.5°x0.5°)

http://www.cru.uea.ac.uk/cru/data/hrg/

Taylor Diagrams (whole domain - annual)

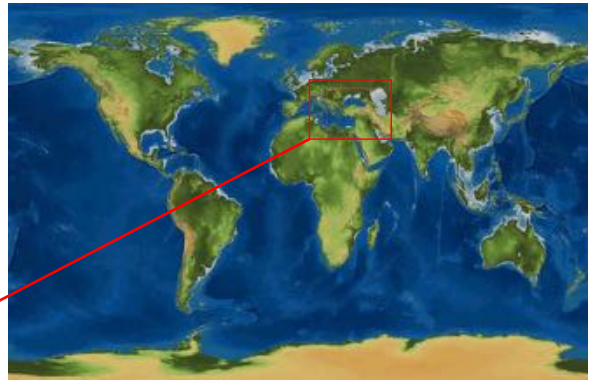
Temperature

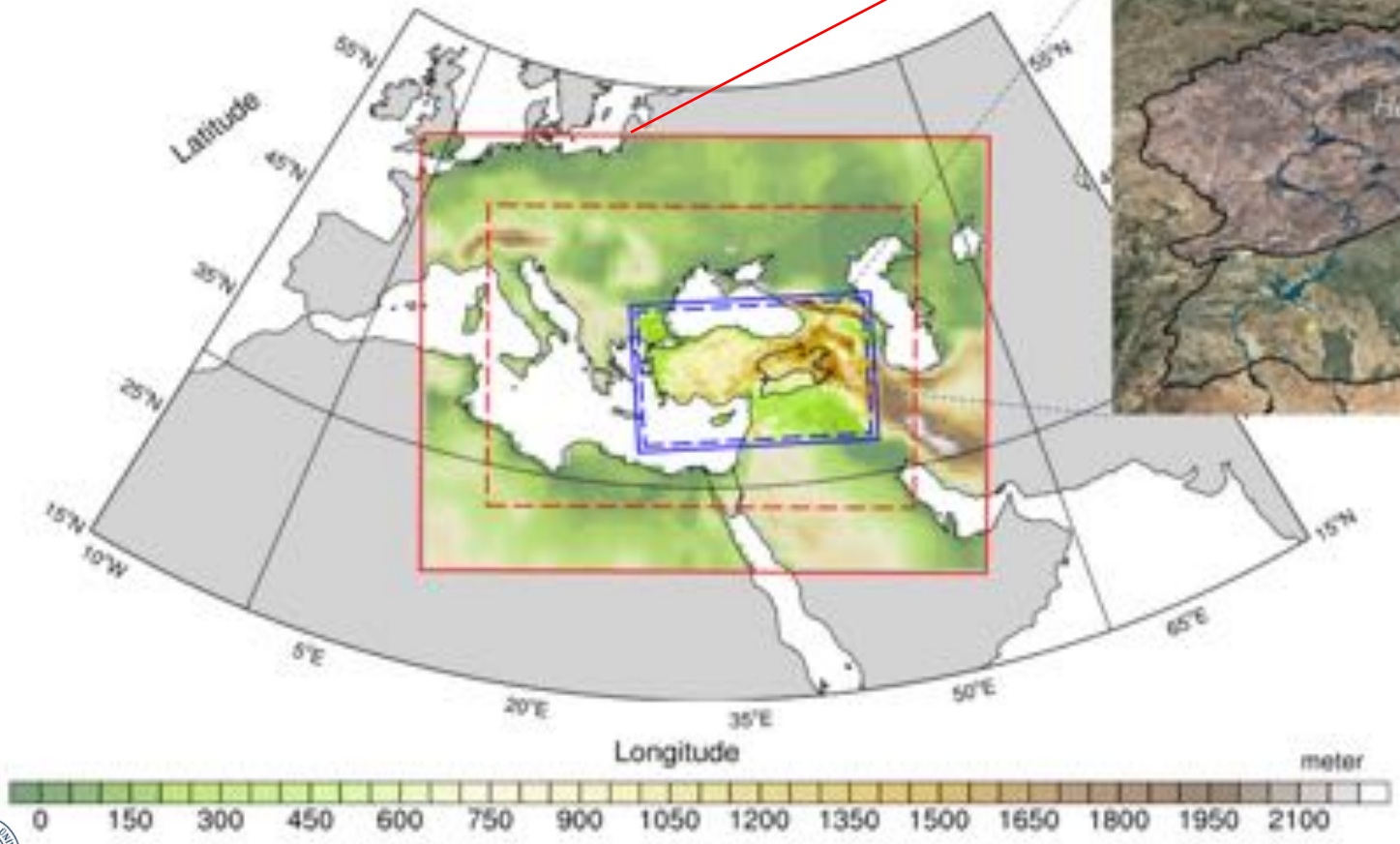
Precipitation



Study Domain

- Eastern Mediterranean and Black Sea (OD-48 km)
- Turkey (TR-12 km //with subgrid-3km)
- Euphrates & Tigris Basin





Model Configuration

Domain name	OD48 (48 km)	TR12 (12 km)
Grid number (y,x), Vertical Resolution	75x95, 18 level	100x160, 23 level
Center (latitude, longitude)	40, 32	38.7, 37
Initial and Boundary Conditions (atmosphere, sst)	• **NNRP, OI_WK** • **EC-EARTH**	• **OD48 outputs**
Boundary Condition Parameters (nspgx,nspgd)	12,12	18,18
Boundary Layer Model	Holtslag PBL	Holtslag PBL
Cumulus Convection Scheme	Grell	Grell
Cumulus Closure Scheme	Fritsch & Chappell	Fritsch & Chappell
Moisture Scheme	SUBEX	SUBEX
Ocean Flux Scheme	Zeng	Zeng
Radiation Model	CCSM	CCSM

Land surface processes in RegCM4

- **BATS** (Biosphere-Atmosphere Transfer Scheme)

  Subgridding

  (3 km resolution)

- **CLM** (Community Land Model)

Landuse Maps

1993 period

Pre-GAP

- GLCC (USGS)
- Non-irrigated

2000 period

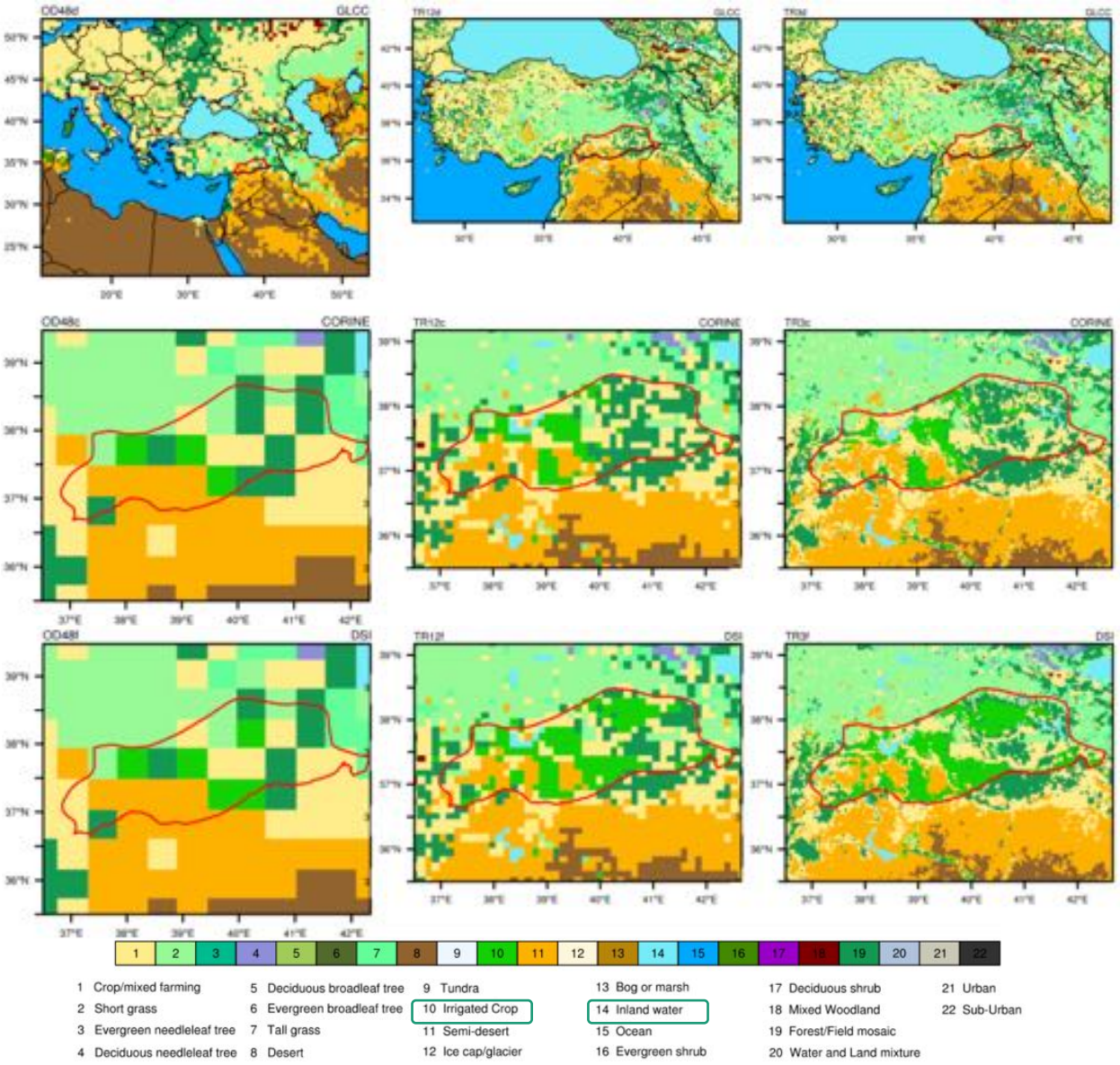
Current GAP (25%)

- CORINE (EEA)
- Partly irrigated

Future period

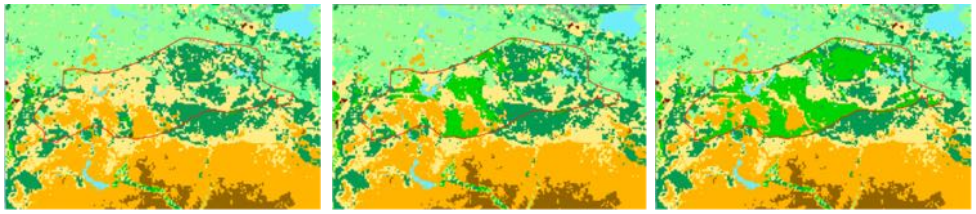
Future GAP (%100)

- DSI (Turkish State Hydraulic Work)
- Fully irrigated



Experimental Design

No	Forcing Data	Land Use Map	Simulation Period
1	NCEP/NCAR Reanalysis	Non-irrigated	1991-2010
2	NCEP/NCAR Reanalysis	Partly irrigated	1991-2010
3	NCEP/NCAR Reanalysis	Fully irrigated	1991-2010
4	EC-EARTH	Non-irrigated	1986-2008
5	EC-EARTH / RCP 4.5	Non-irrigated	2046-2065
6	EC-EARTH / RCP 8.5	Non-irrigated	2046-2065
7	EC-EARTH / RCP 4.5	Fully irrigated	2046-2065
8	EC-EARTH / RCP 8.5	Fully irrigated	2046-2065
9	EC-EARTH / RCP 4.5	Fully irrigated	2081-2100
10	EC-EARTH / RCP 8.5	Fully irrigated	2081-2100

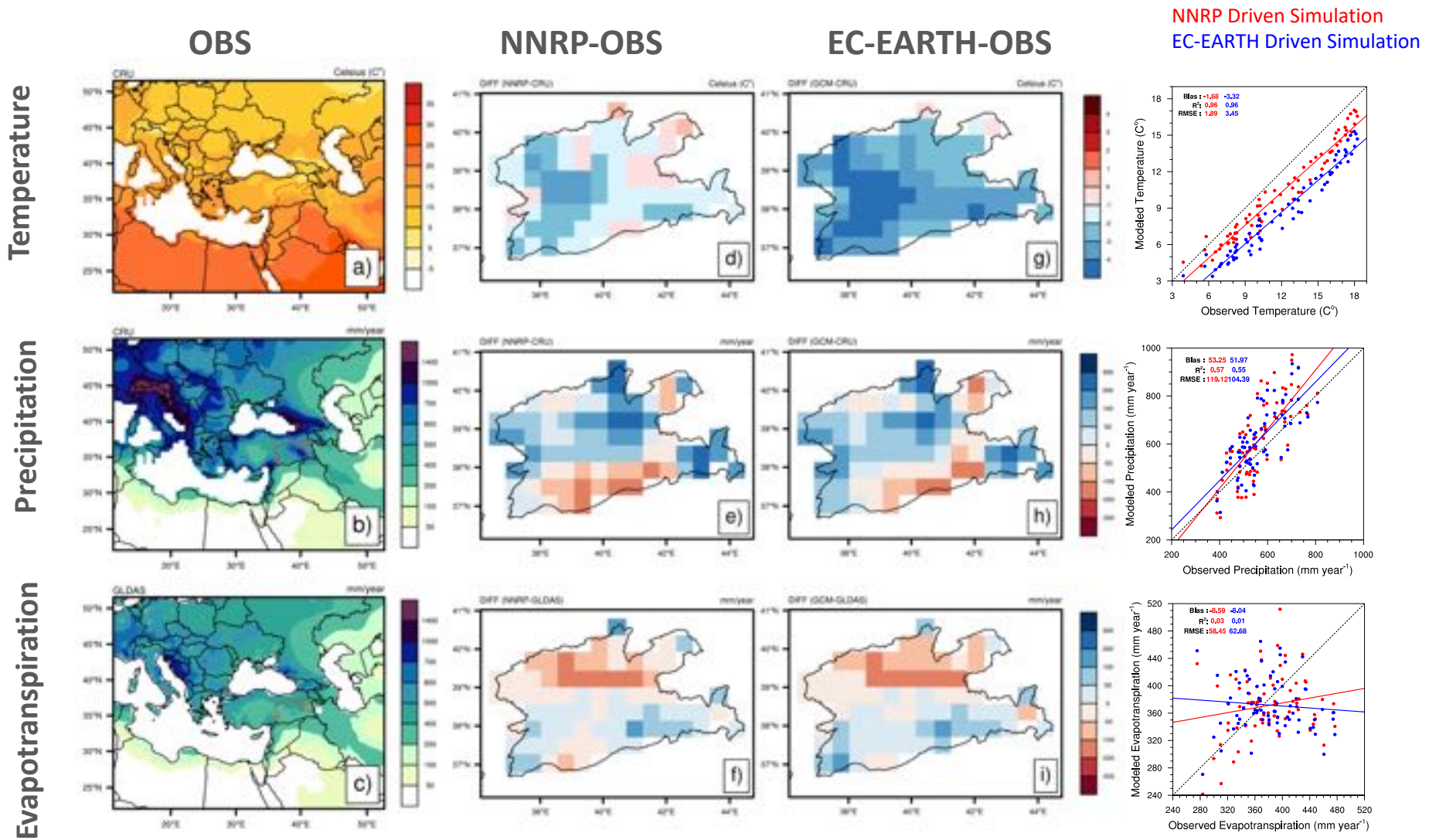


(Non-irrigated) (Partly irrigated) (Fully irrigated)

Model Evaluation

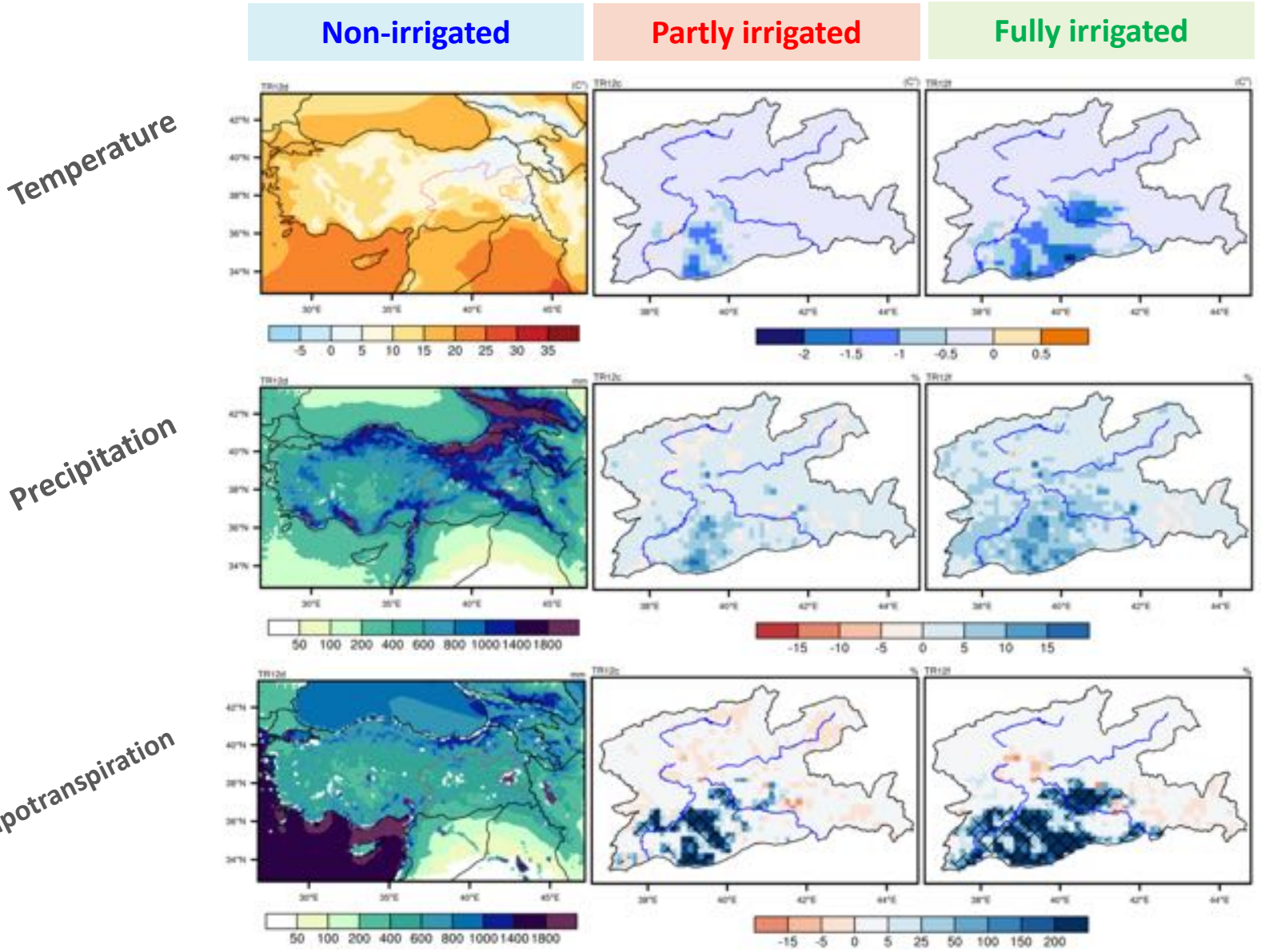
48 km (1991-2008)

No	Forcing Data	Land Use Map	Simulation Period
1	NCEP/NCAR Reanalysis	Non-irrigated	1991-2010
4	EC-EARTH	Non-irrigated	1986-2008

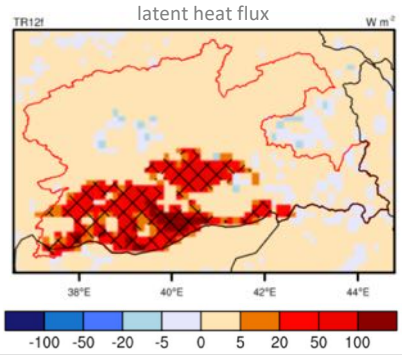


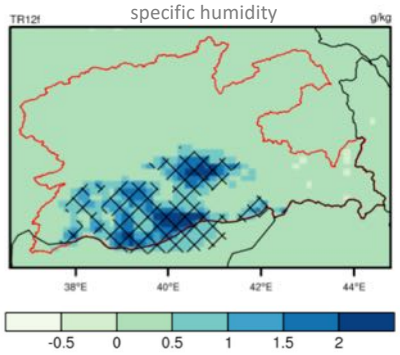
Effects of LULC change

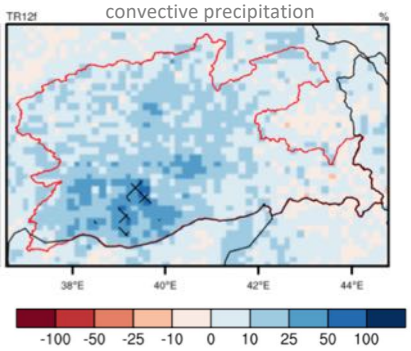
No	Forcing Data	Land Use Map	Simulation Period
1	NCEP/NCAR Reanalysis	Non-irrigated	1991-2010
2	NCEP/NCAR Reanalysis	Partly irrigated	1991-2010
3	NCEP/NCAR Reanalysis	Fully irrigated	1991-2010

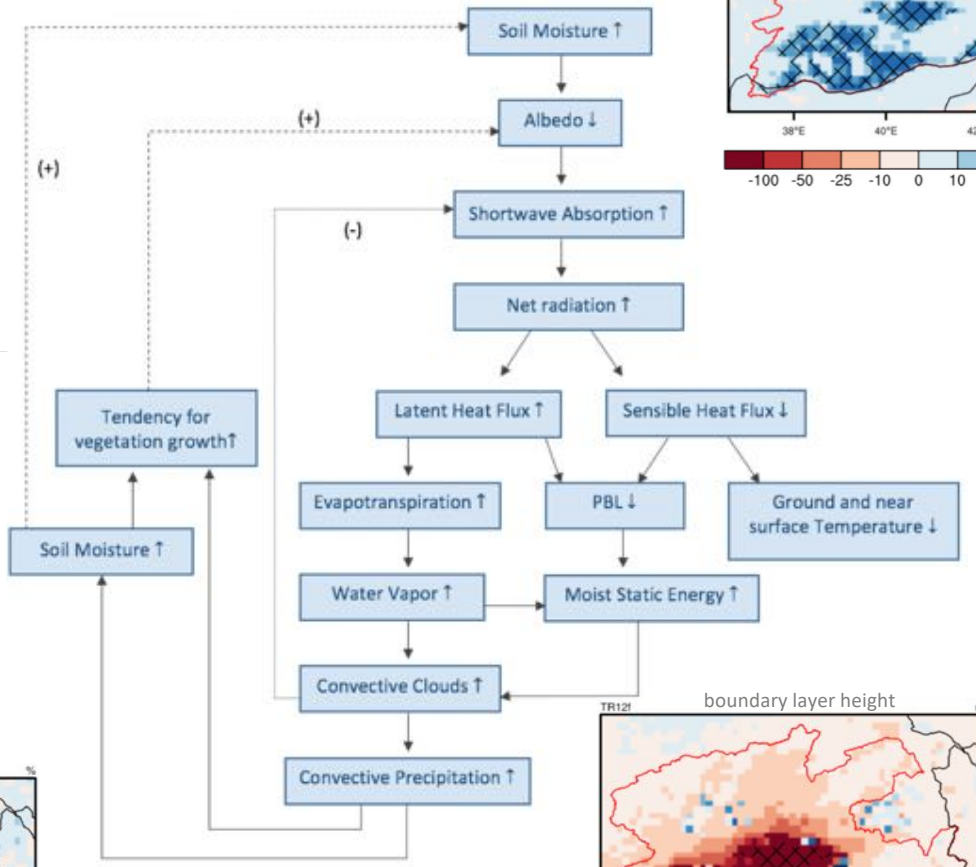


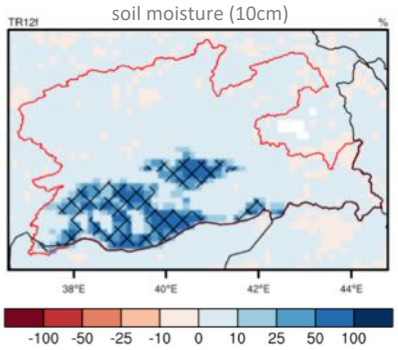
Effects of irrigation

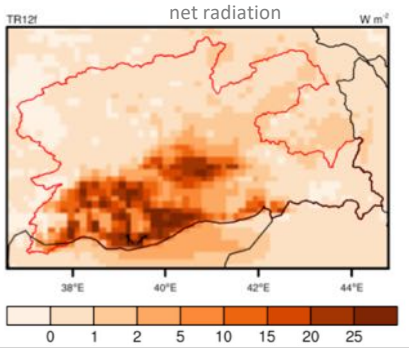


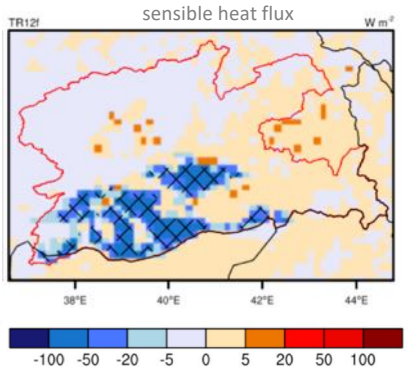


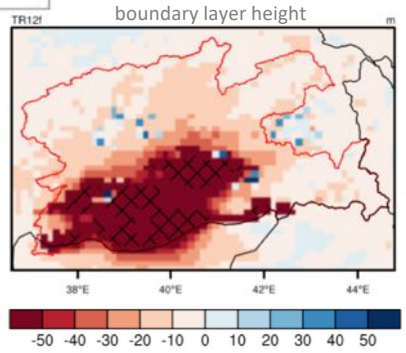






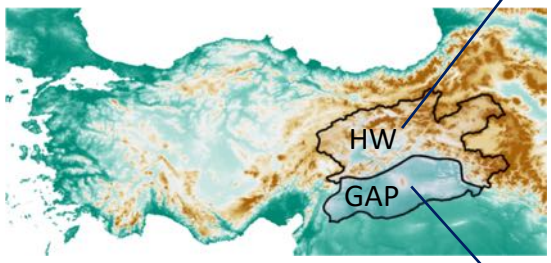


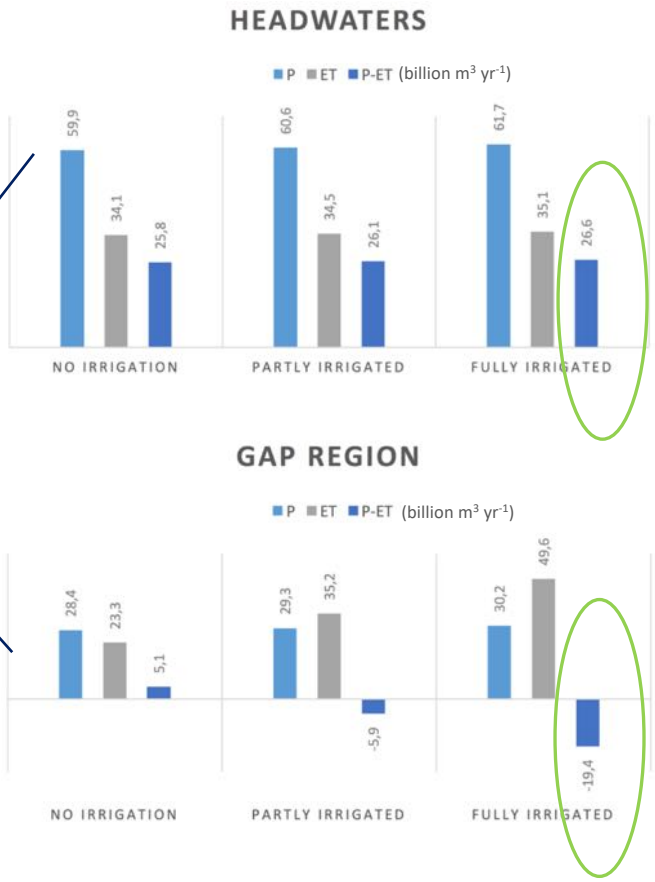




Conceptual diagram of the land-atmosphere interactions due to a change in soil moisture. The dashed lines show a positive feedback, while the dotted line represents a negative feedback. Figure is adopted from the studies of Pitman (2003), Lawrence & Slingo (2005) and Seneviratne et al. (2010).

Effects of LULC changes on the water budget





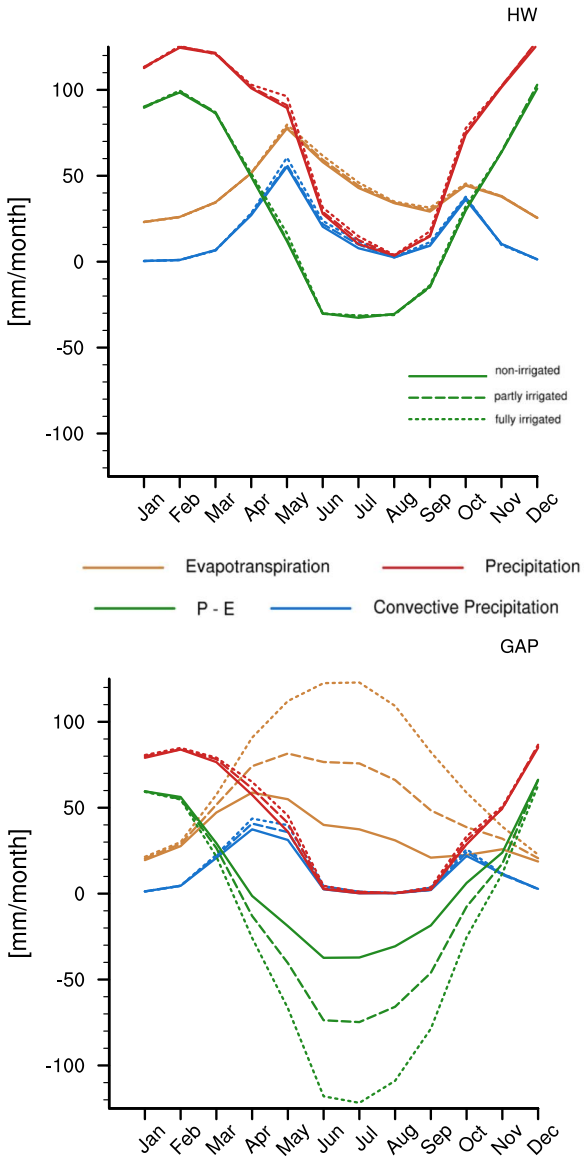
1991-2010

increase of evapotranspiration in GAP

- 51% with partly irrigated map
- 114% with fully irrigatied map

Water release to downstream countries

15.8 (billion m^3 yr^{-1})



What happens if we ONLY change the LULC?

- Land use and land cover changes cause
  - annual surface **temperature decrease** by about 0.4 ^{0}C and 0.8 ^{0}C
    (irrigation's cooling effect)
  - **precipitation increase** 3% and 7%, mostly in spring.
    (soil moisture ↑ ≫ latent heat flux ↑ ≫ convective precipitation ↑)
  - **increase in evapotranspiration** amounts by 51% and 114% compared to the pre-GAP conditions, which means significant water loss from the region.
- The increasing **water demand** of the irrigated region (GAP) is currently **barely compensated** including the downstream water release by the headwaters of the Euphrates & Tigris basin.

Let's add the effects of increasing greenhouse gas concentrations!

INTEGRATED Effects of LULC change + RCPs

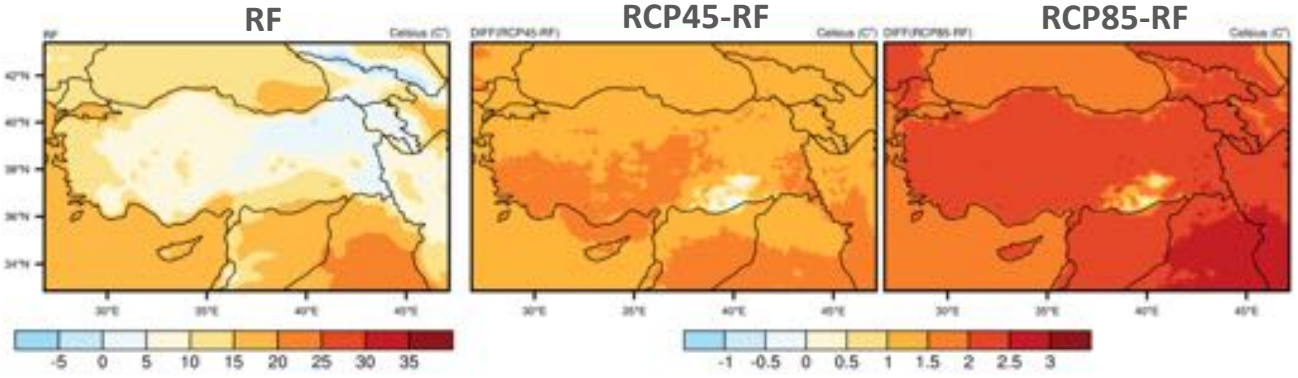
No	Forcing Data	Land Use Map	Simulation Period
4	EC-EARTH	Non-irrigated	1986-2008
7	EC-EARTH / RCP 4.5	Fully irrigated	2046-2065
8	EC-EARTH / RCP 8.5	Fully irrigated	2046-2065

EC-EARTH driven 12 km simulations 2046-2065

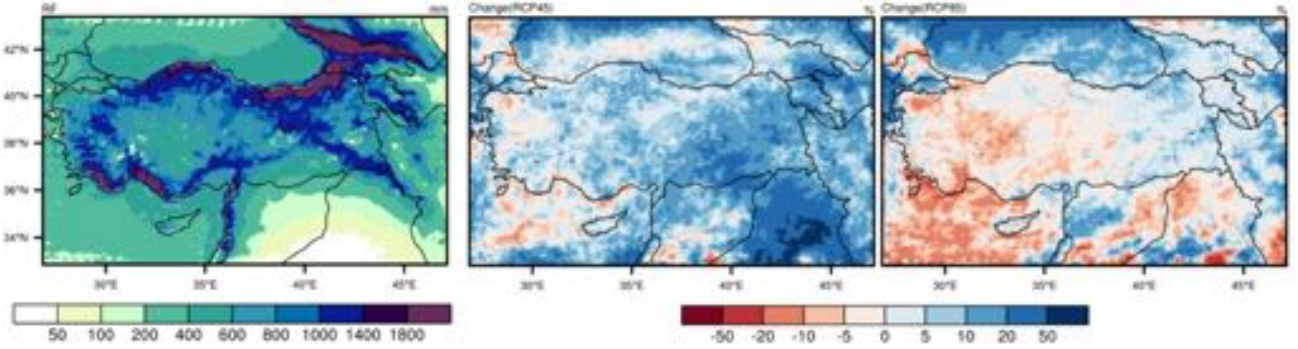
Non-irrigated | **Fully irrigated**

RF | RCP45-RF | RCP85-RF

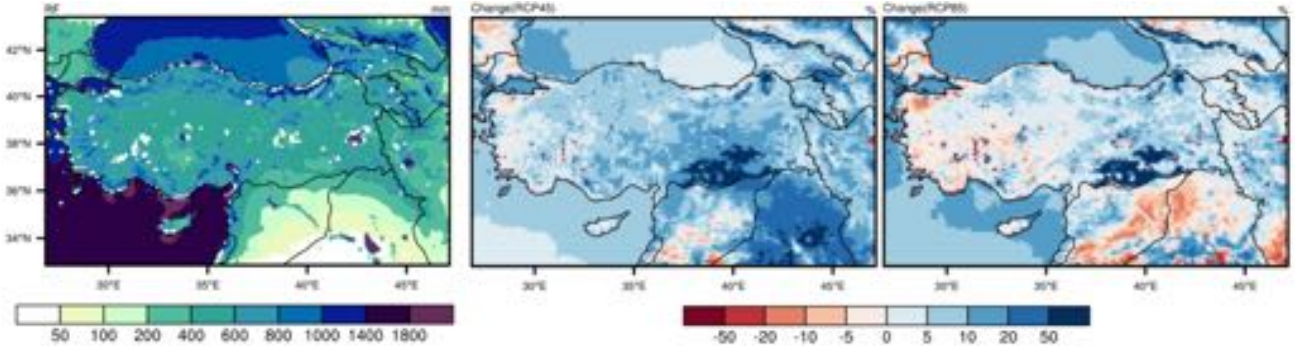
Temperature



Precipitation



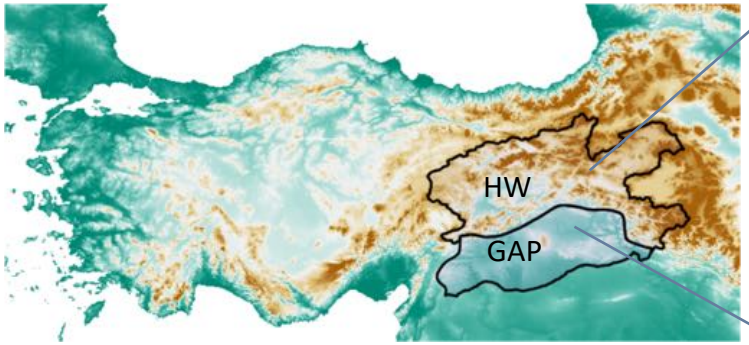
Evapotranspiration



Seasonal Cycle (P-E)

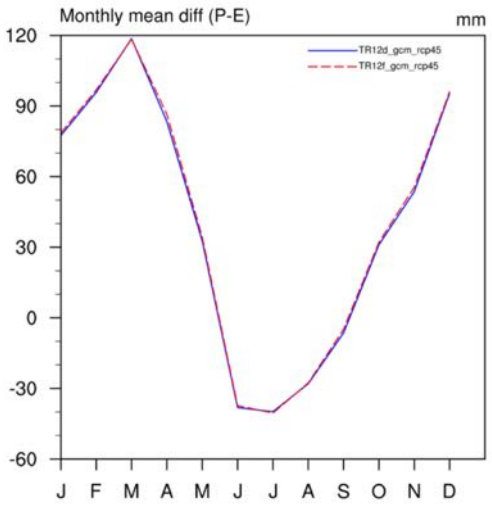
Headwaters

2046-2065

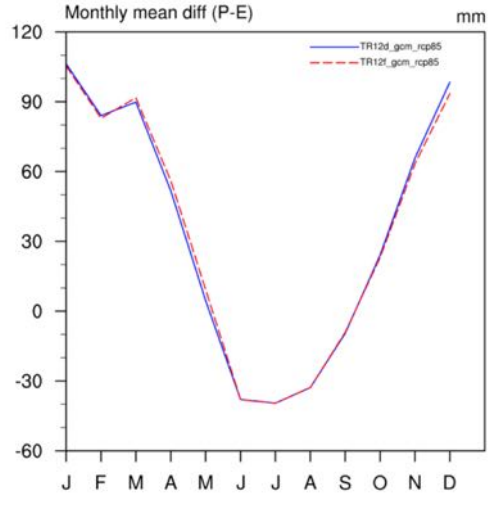


GAP region (irrigation projects)

RCP 4.5

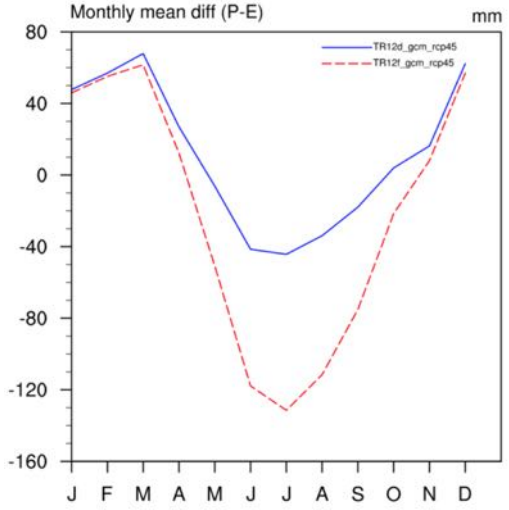


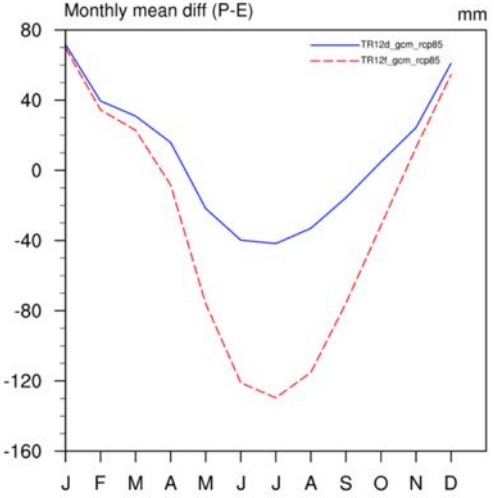
RCP 8.5



Non-irrigated

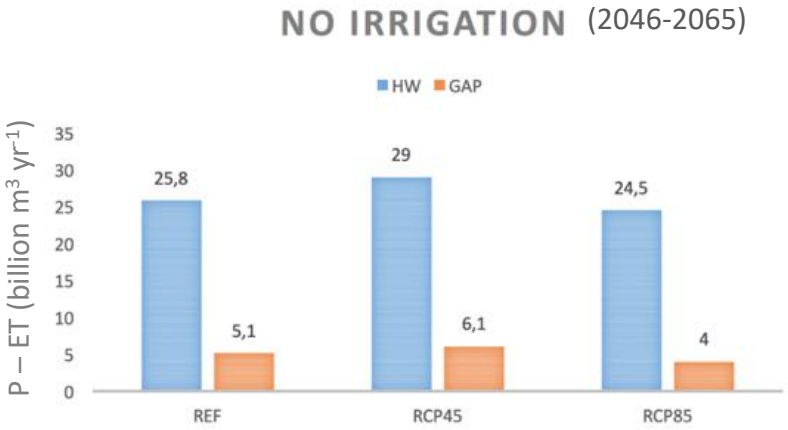
Fully irrigated

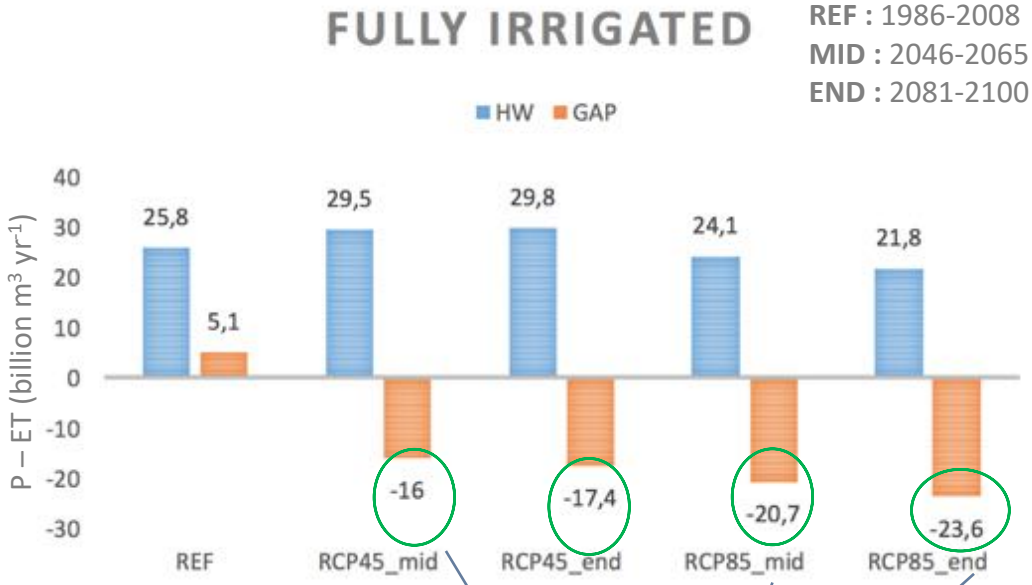




Effects of RCP scenarios
(GAP Region)

Integrated effects (LULC + RCPs)





Water release to downstream countries

15.8 (billion m^3 yr^{-1})

Photo credit : gap.gov.tr

Conclusions

- Our experiment reveals that the regional water budget will be adversely affected by the **water loss through the increased evapotranspiration**.
- The increasing **water demand** of the irrigated region (GAP) is currently **barely compensated** by the headwaters of the Euphrates & Tigris basin.
- Temperature decrease caused by increased evapotranspiration will be at the same order of the increase in temperature due to RCP forcing. Hence, the **temperature of the irrigated region** will not be changed significantly in the future.
- The water of the region is primarily partitioned between energy production, irrigation and release for the downstream countries, the dramatic increase in water loss through evapotranspiration has potential to **alter the water management practices and policy measures** in the larger region.

Future work

- Precipitation recycling
- Irrigation techniques (flood, sprinkler, drip)

Thank you*

yelizyilmaz@itu.edu.tr

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Research Grant Number : 114Y114

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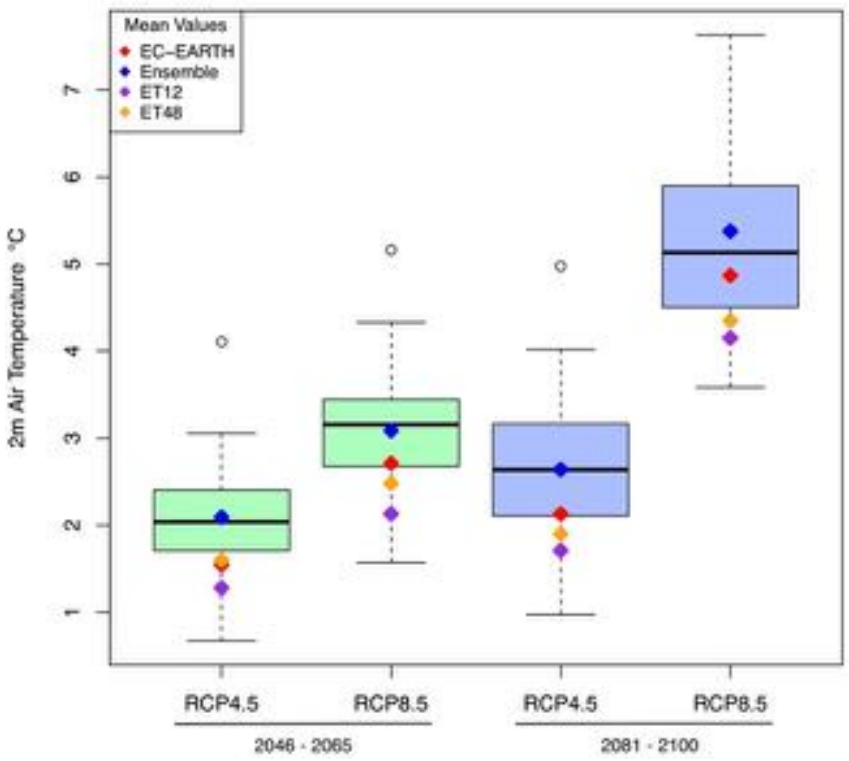
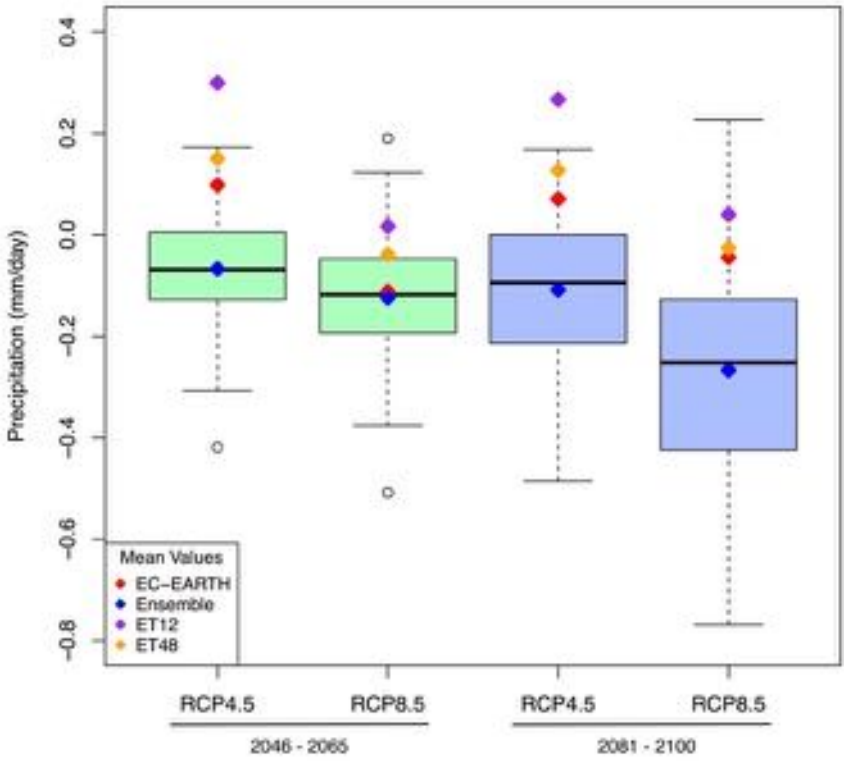
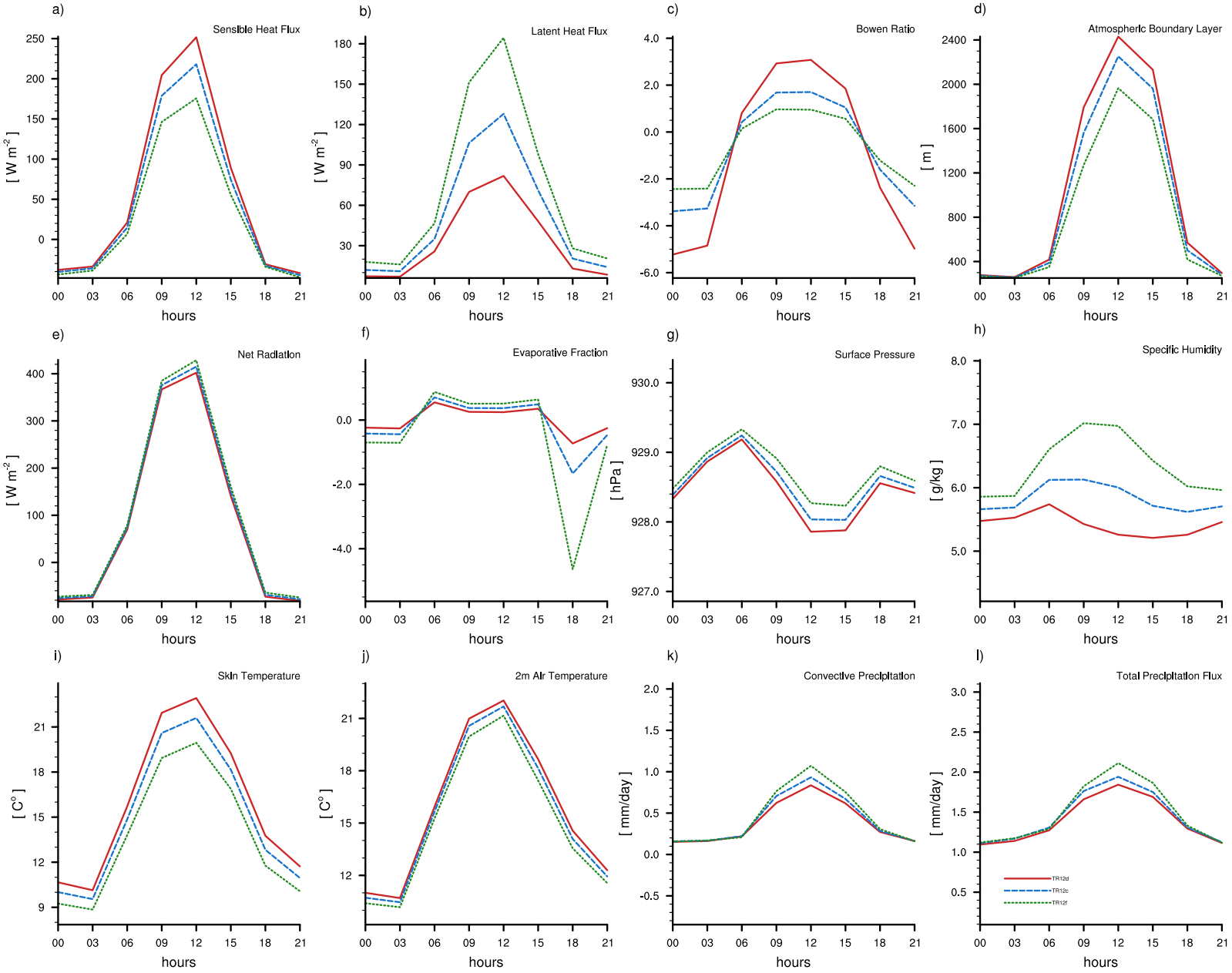
EC-EARTH

Performance Evaluation

Future-Reference (Turkey)






a)
Sensible Heat Flux
[W m-2]
hours
b)
Latent Heat Flux
[W m-2]
hours
c)
Bowen Ratio
hours
d)
Atmospheric Boundary Layer
[m]
hours
e)
Net Radiation
[W m-2]
hours
f)
Evaporative Fraction
hours
g)
Surface Pressure
[hPa]
hours
h)
Specific Humidity
[g/kg]
hours
i)
Skin Temperature
[C°]
hours
j)
2m Air Temperature
[C°]
hours
k)
Convective Precipitation
[mm/day]
hours
l)
Total Precipitation Flux
[mm/day]
hours
TR12d
TR12c
TR12f

LULC change + RCPs effect