Climate Change Impacts on the water Resources

An Overview of global impacts and techniques to assess at local scale

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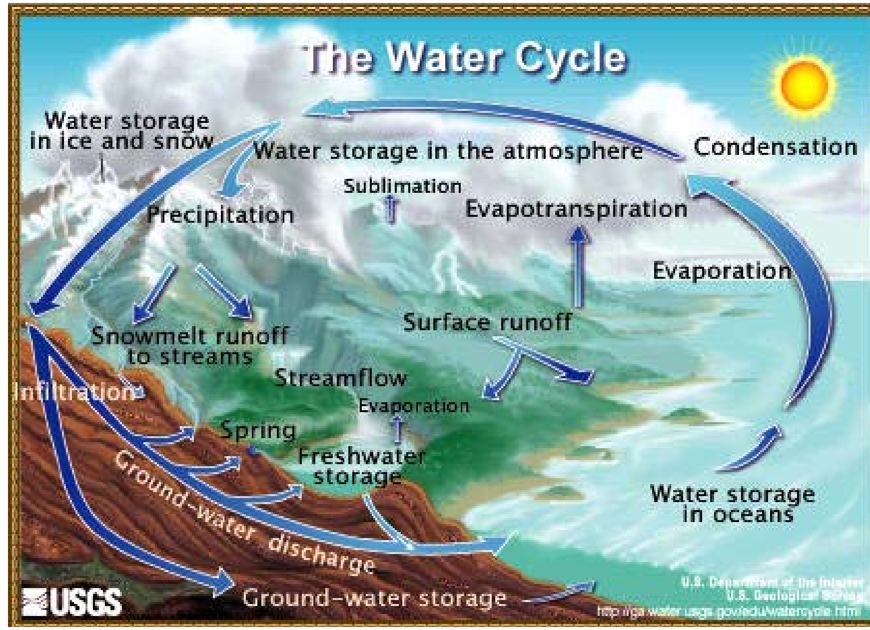
Outline

- **Effects on the hydrological cycle**
- **Impact on the water resources**
- **Techniques to asses at local scale: Downscaling from GCMs outputs**
- **Conclusions**

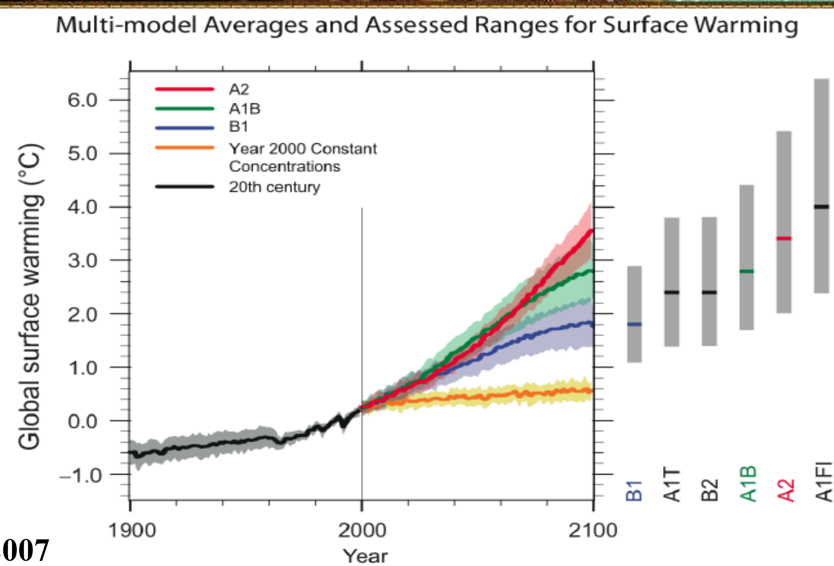
Effects on the Hydrological cycle

- **Precipitation**
- **Evaporation**
- **Runoff. River flows**
- **Water storage**
- **Soil moisture**



Hydrological cycle:
Inflows, outflows, and storage

$$\frac{ds}{dt} + Q(t) - I(t) = 0$$



IPCC, 2007

Effects on the Hydrological Cycle

- A1B: best estimated 2.8 C, range 1.7- 4.4 C
- +ΔPr in tropics, high Latitudes
- -ΔPr Mid latitudes, lower in 20 % (0.8 mm/day
- increase of risks:

  droughts sub tropical, low and mid latitudes

  Floods: tropical and highs latitudes regions

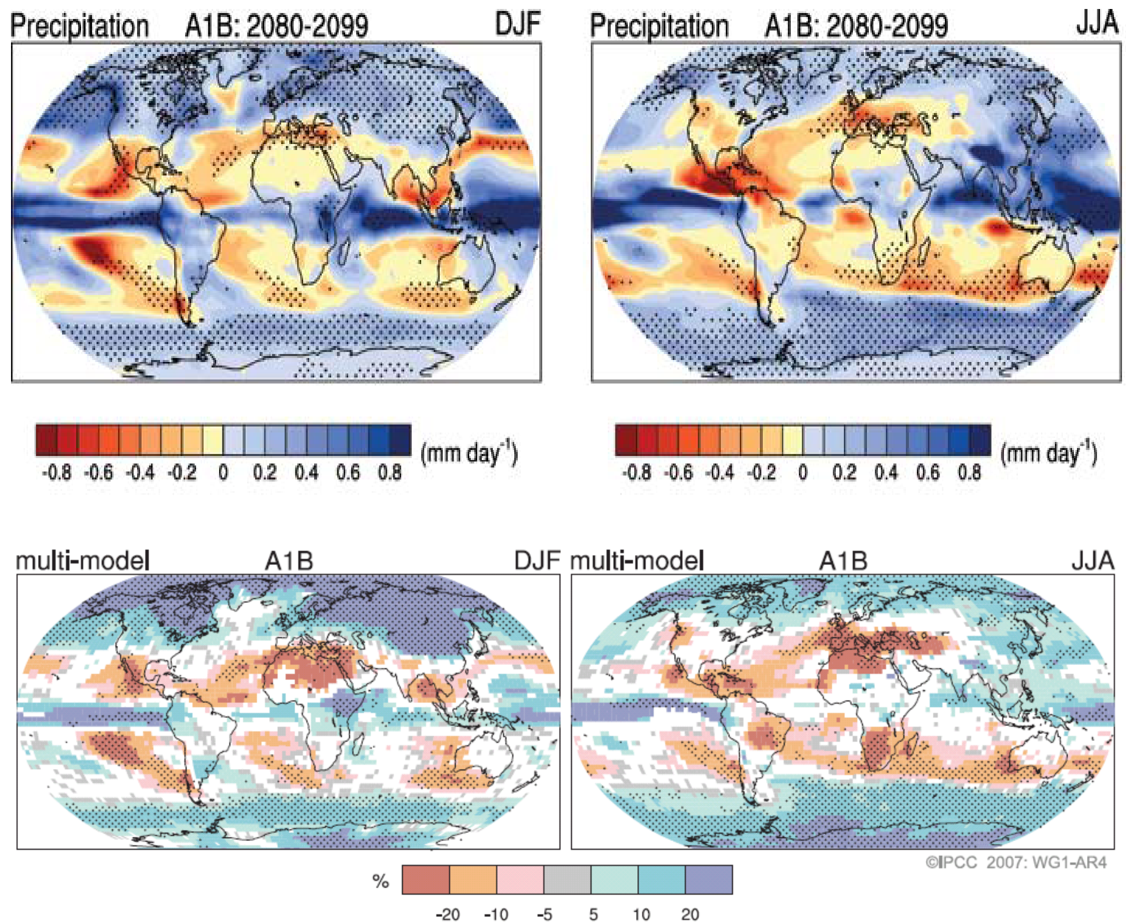


Figure SPM.7. *Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}*

Effects on the hydrological cycle

- Soil moisture decreases in high latitudes where the snow cover diminishes, +Δ with Pr and Ev.
- Runoff decreases in central America, south Europe (30 %), increase high latitudes
- Evaporation increases in most oceans (15-20%)

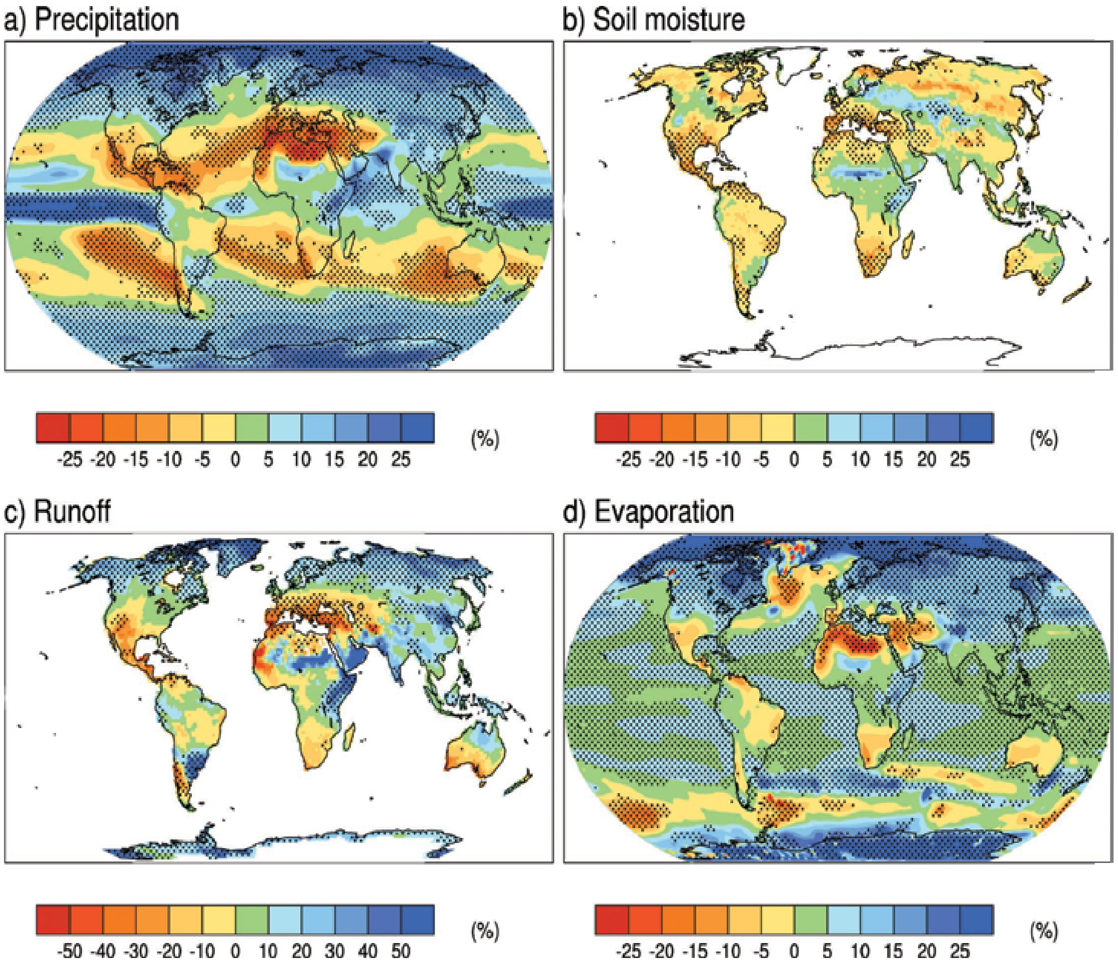


Figure 2.8: Fifteen-model mean changes in (a) precipitation (%), (b) soil moisture content (%), (c) runoff (%), and (d) evaporation (%). To indicate consistency of sign of change, regions are stippled where at least 80% of models agree on the sign of the mean change. Changes are annual means for the scenario SRES A1B for the period 2080–2099 relative to 1980–1999. Soil moisture and runoff changes are shown at land points with valid data from at least ten models. [Based on WGI Figure 10.12]. **IPCC, 2008**

Effects on the Hydrological Cycle

- Groundwater recharge

decrease 70% South West Africa And North Eastern Brazil.

- Increase in Northern China, Western USA in more 30 %.

Water storage in ace and snow:

Glaciers important volume losses by 2050

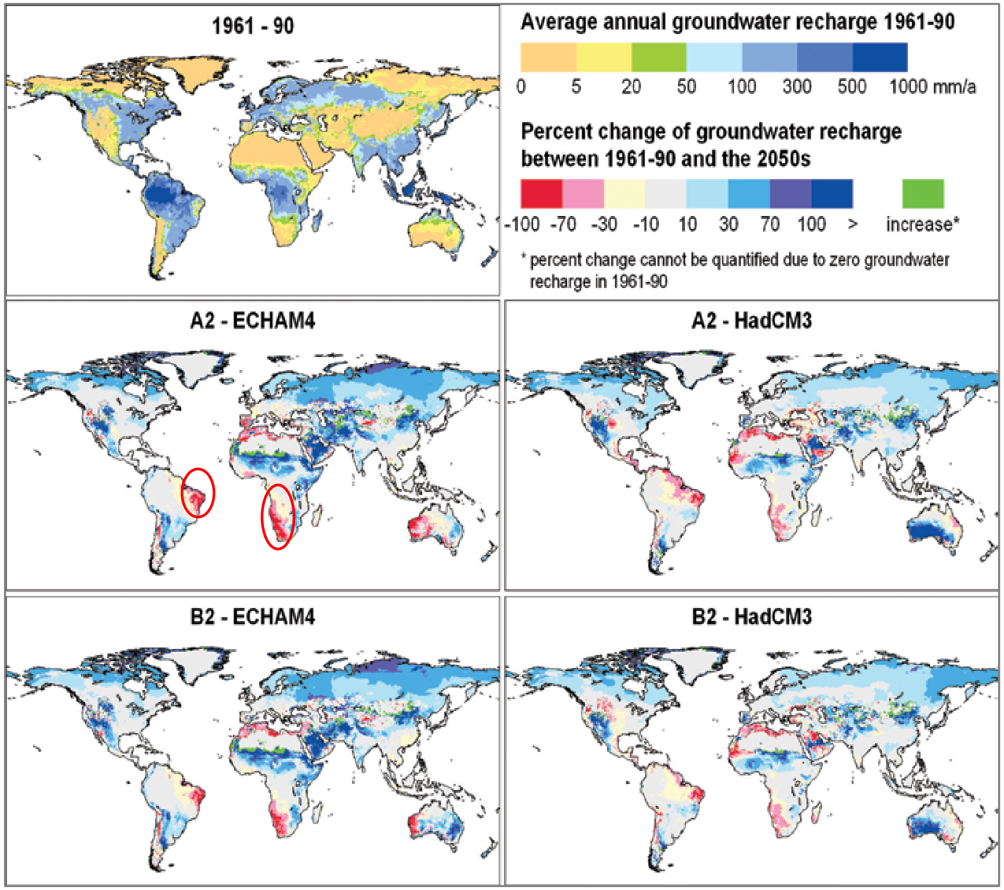
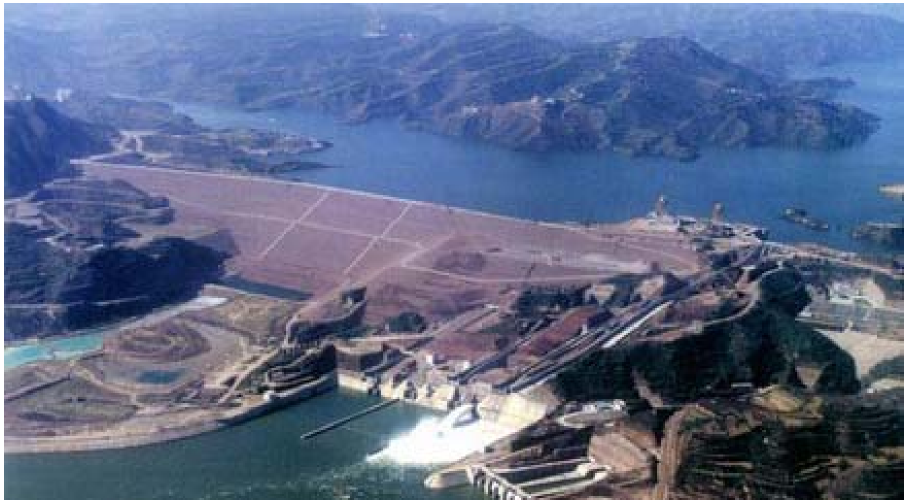


Figure 3.2: Simulated impact of climate change on long-term average annual diffuse groundwater recharge. Percentage changes in 30-year average groundwater recharge between the present day (1961–1990) and the 2050s (2041–2070), as computed by the global hydrological model WGHM, applying four different climate change scenarios (based on the ECHAM4 and HadCM3 climate models and the SRES A2 and B2 emissions scenarios) (Döll and Flörke, 2005). [WGII Figure 3.5]

Impacts on the Water Resources



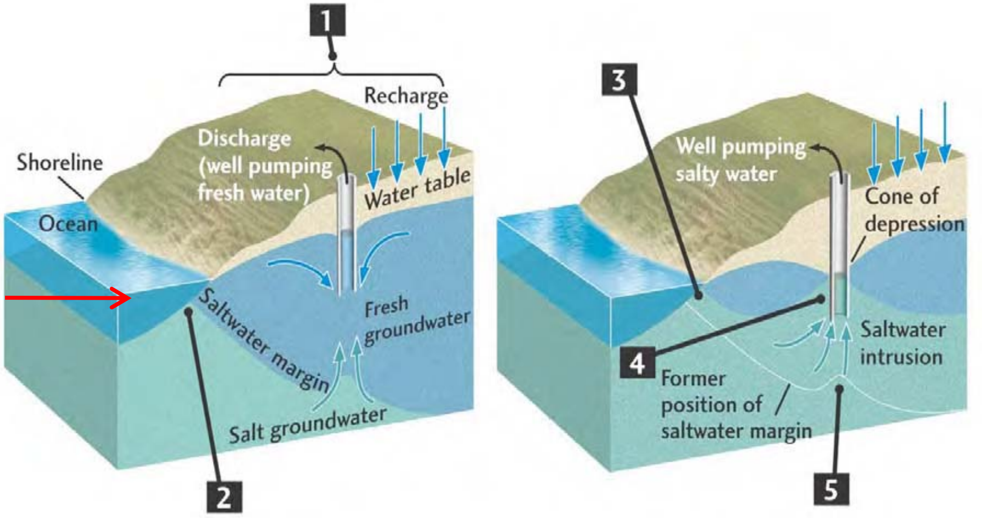
Direct impacts on water availability

- **Water demands**
- **Hydraulic infrastructures**
- **Hydropower. Energy demand**
- **Flood control operation**
- **Recharge**
- **Water Quality**

Water Management

Economic impacts

Rise sea level projections: 0.18 -0.59 m



Impacts on the Water Resources

Table 3.2: Possible impacts of climate change due to changes in extreme precipitation-related weather and climate events, based on projections to the mid- to late 21st century. The direction of trend and likelihood of phenomena are for IPCC SRES projections of climate change. [WGI Table SPM-2; WGII Table SPM-2]

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	Water resources [3.4]	Human health [8.2]	Industry, settlements and society [7.4]
Heavy precipitation events: frequency increases over most areas	Very likely	Damage to crops; soil erosion; inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property

	Estimated population in water-stressed river basins in the year 2050 (billions)	
	Arnell (2004)	Alcamo et al. (2007)
1995: Baseline	1.4	1.6
2050: A2 emissions scenario	4.4–5.7	6.4–6.9
2050: B2 emission scenario	2.8–4.0	4.9–5.2

IPCC, 2008

Impacts on the Water Resources

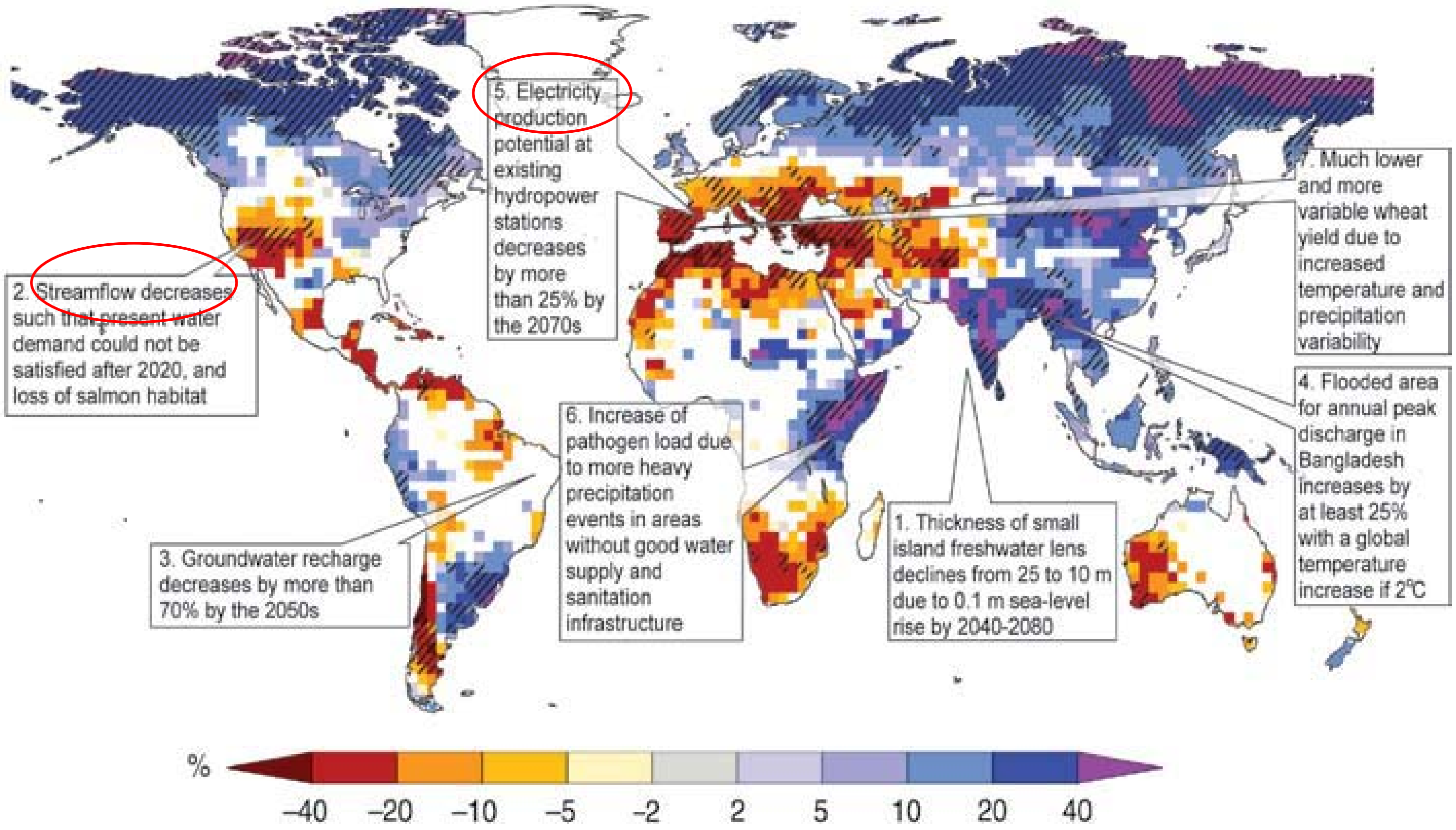


Figure 3.4: Illustrative map of future climate change impacts related to freshwater which threaten the sustainable development of the affected regions.

IPCC, 2008

Downscaling from GCMs

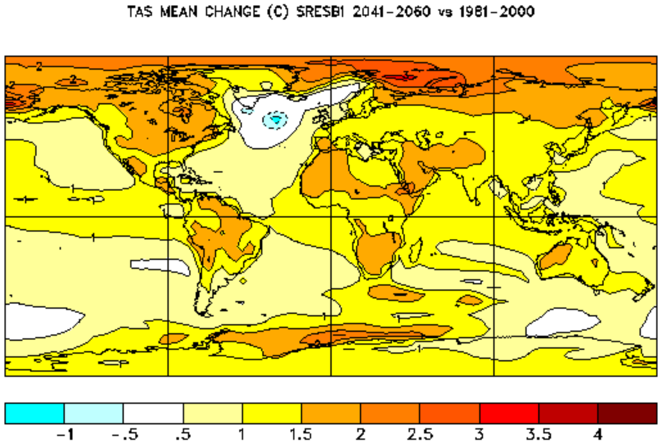
Downscaling: To reduce in scale. It allows to increase the resolution of data from GCMs to get local scale surface weather.

Statistical

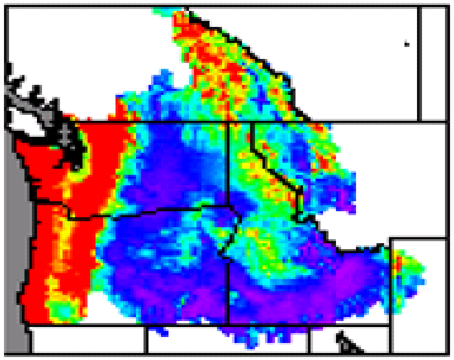
It is based on statistical relationship between the large scale climate (GCMs) and local climate variables

Dynamic

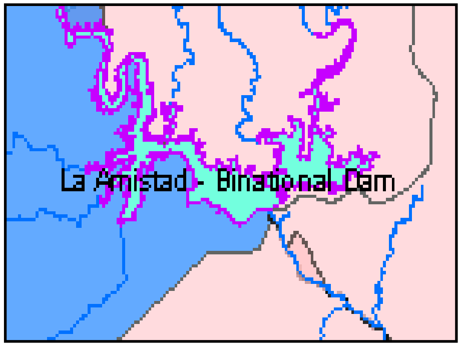
Extracting local –scale data, developing RCMs with the coarse GCMs data used as BC



300 km Global

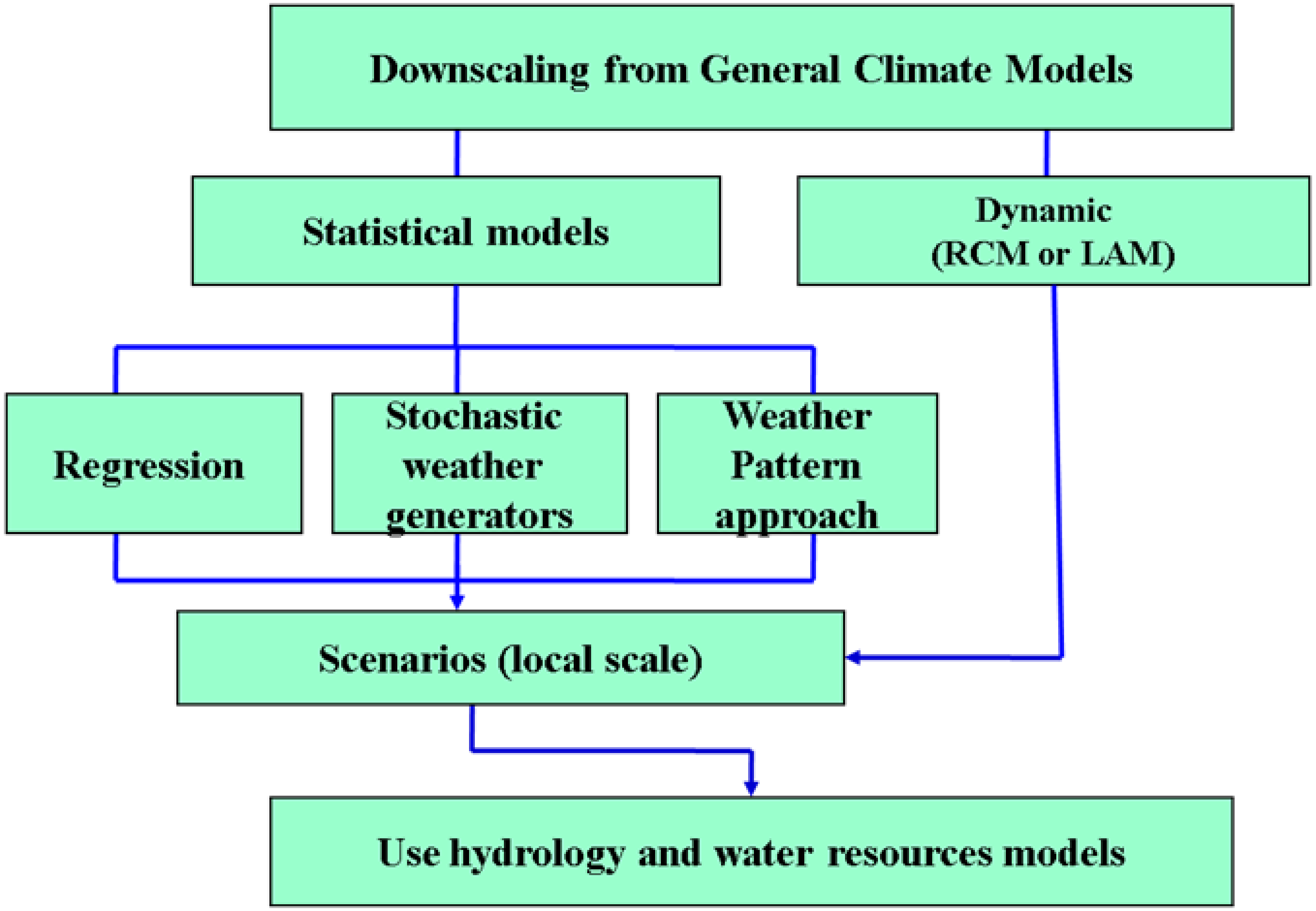


50 km



Local 10 km , 1km

Downscaling from GCMs Output



Statistical Downscaling Methods

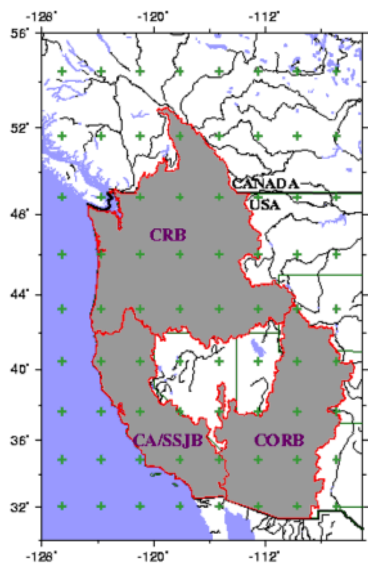
1. **Regression Methods:**
   Linear and no linear relationship between local observed Variables and model predictors(GCMs). Include conical correlations, recent approach Artificial Neural Network (ANN)

2. **Stochastic Weather Generators**
   Use statistical models of observed sequences to generate synthetic times series of weather data. It is a conditional probability. Calculate the Prob of local and regional weather patterns. Use of Markov models.

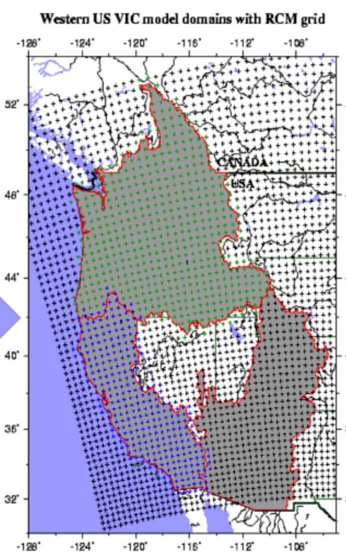
3. **Weather Pattern Approach**
   Relationship between large scale pattern and a set of local surface climate conditions. Use GCMs projections with derived data to estimate climate change impacts at local scale.

Dynamic Downscaling Method

- Dynamic Downscaling is based on fine spatial-scale atmospheric model. Use complex algorithms to describe atmospheric process.
- Extract the local –scale weather data from global scale GCMs. Develop Regional Climate Models. RCMs are based on numerical weather simulation.
- High resolution: 10 – 50 km. It can cover a region, watershed, or countries.

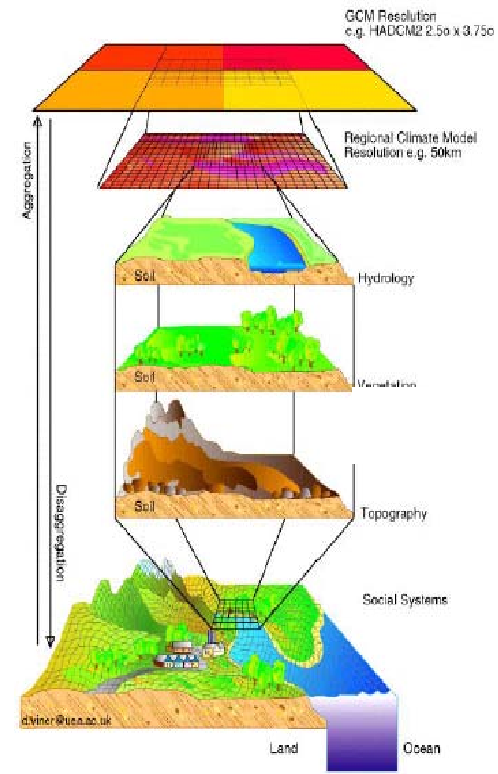


PCM grid : 2.5º x 3.75º

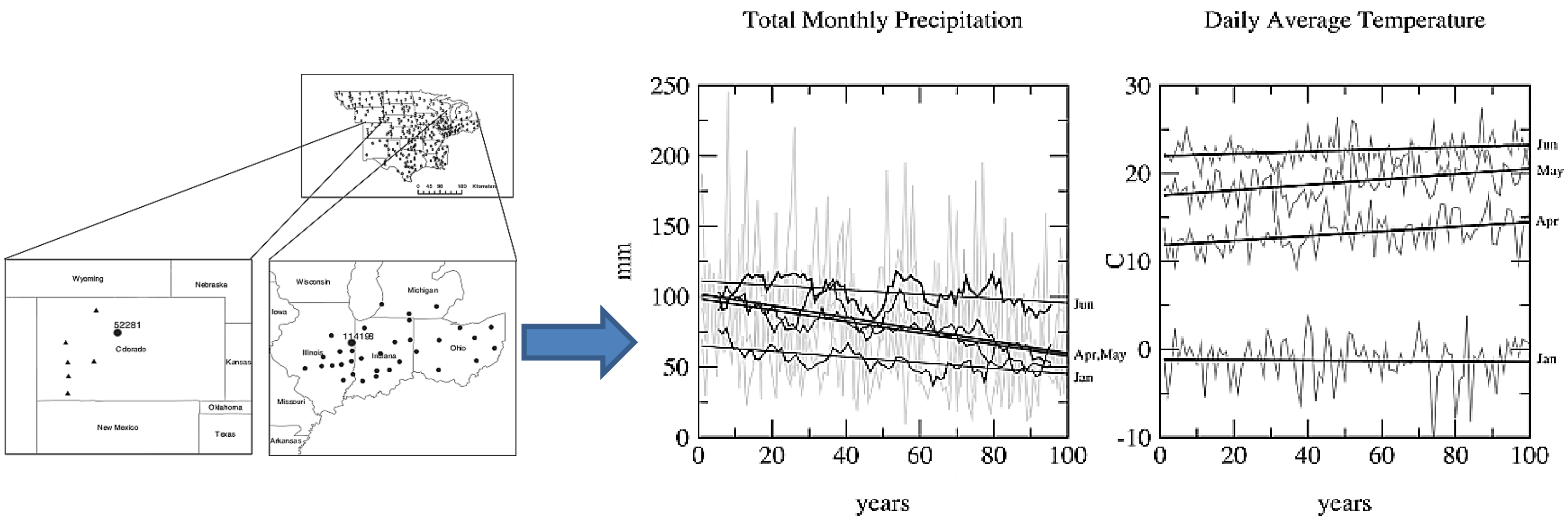


RCM grid : 50 x 50km

From Wood, 2003



Downscaling Applications



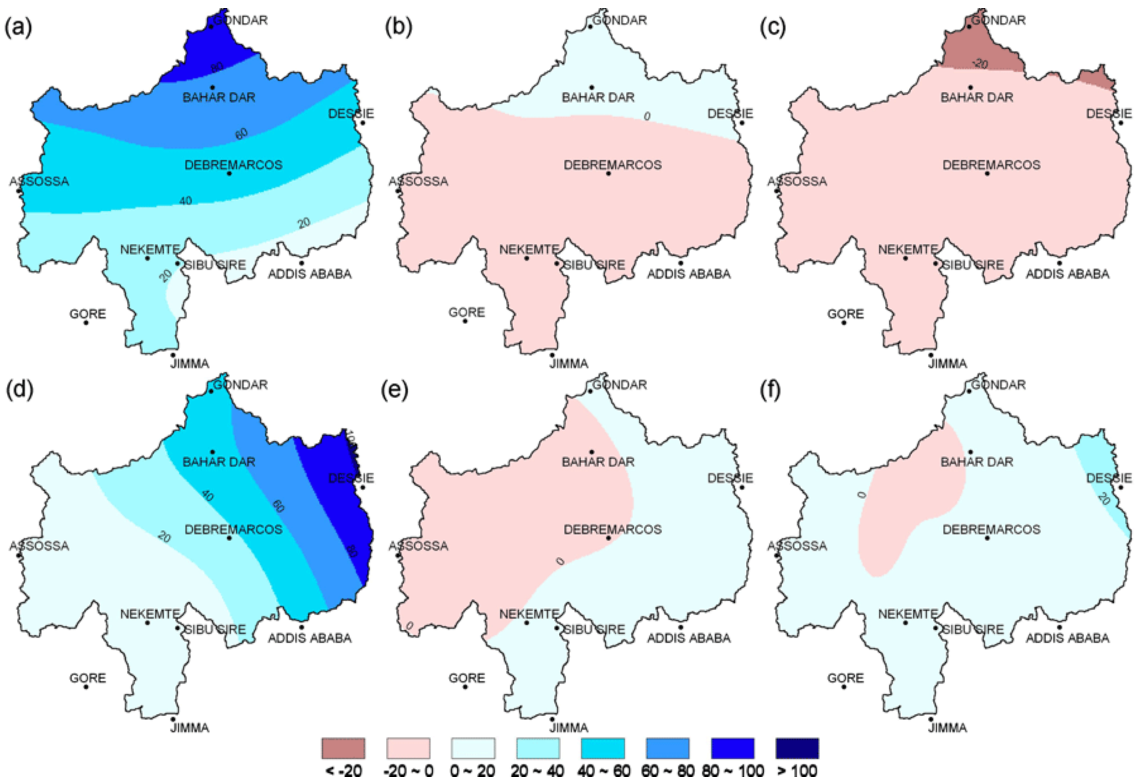
A nearest –neighbor algorithm based on nonparametric stochastic water generator to generate synthetic climate time series

Total monthly precipitation for 100 years times for warmer-drier spring scenarios . Regional averaged time series (shaded lines), the 10-year moving averages (solids lines), and the linear trends for January, April, May, and June are shown with straight lines. Daily average temperature for the indicated months is shown in the right graph, with regionally averaged time series and the linear trend for the 100 years.

Yates et al (2003).

Downscaling Applications

Conditional generation method used to generate monthly precipitation time series for the upper Blues Nile Basin in Ethiopia.



Spatial Distribution of annual precipitation changes (%) by the 2050s for Six GCMs: (a) CCSR, (b) CGCM, (c) CSIRO, (d) ECHAM, (e) GFDL, and (f) HADCM. For A2 scenario

Kim and Kaluarachchi, 20008

Downscaling Applications

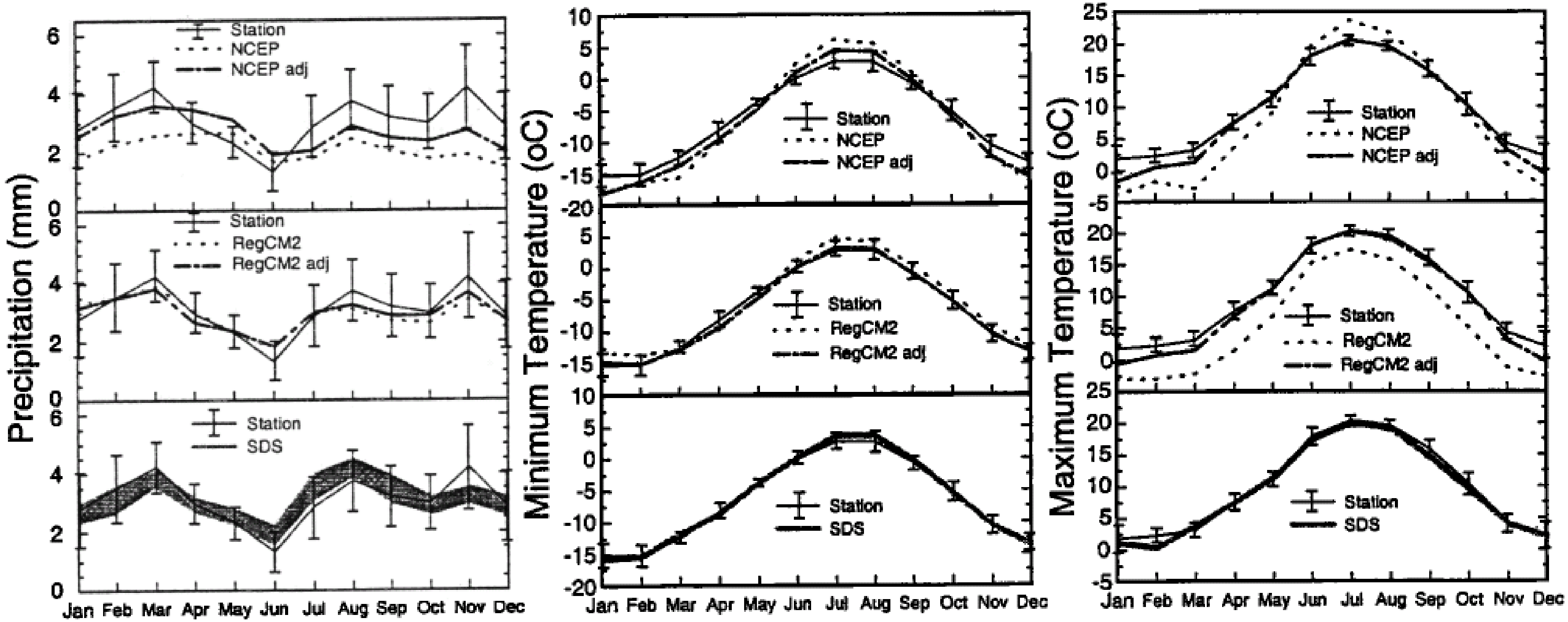


Figure 1. Downscaled monthly mean daily (a) P, (b) Tmin and (c) Tmax for WYs 1980-86, compared with area-averaged station data for the Animas River basin. The error bars for Station data correspond to ± 2 SE. The dotted lines for NCEP and RegCM2 represent the uncorrected model output. The gray shading for the SDS results shows the range of values produced by an ensemble of twenty members.

Wilby et al. 2000

National Center for Environmental Prediction/ National Centerf or AtmosphericR esearch(N CEP/NCAR) re-analys

Downscaling Applications

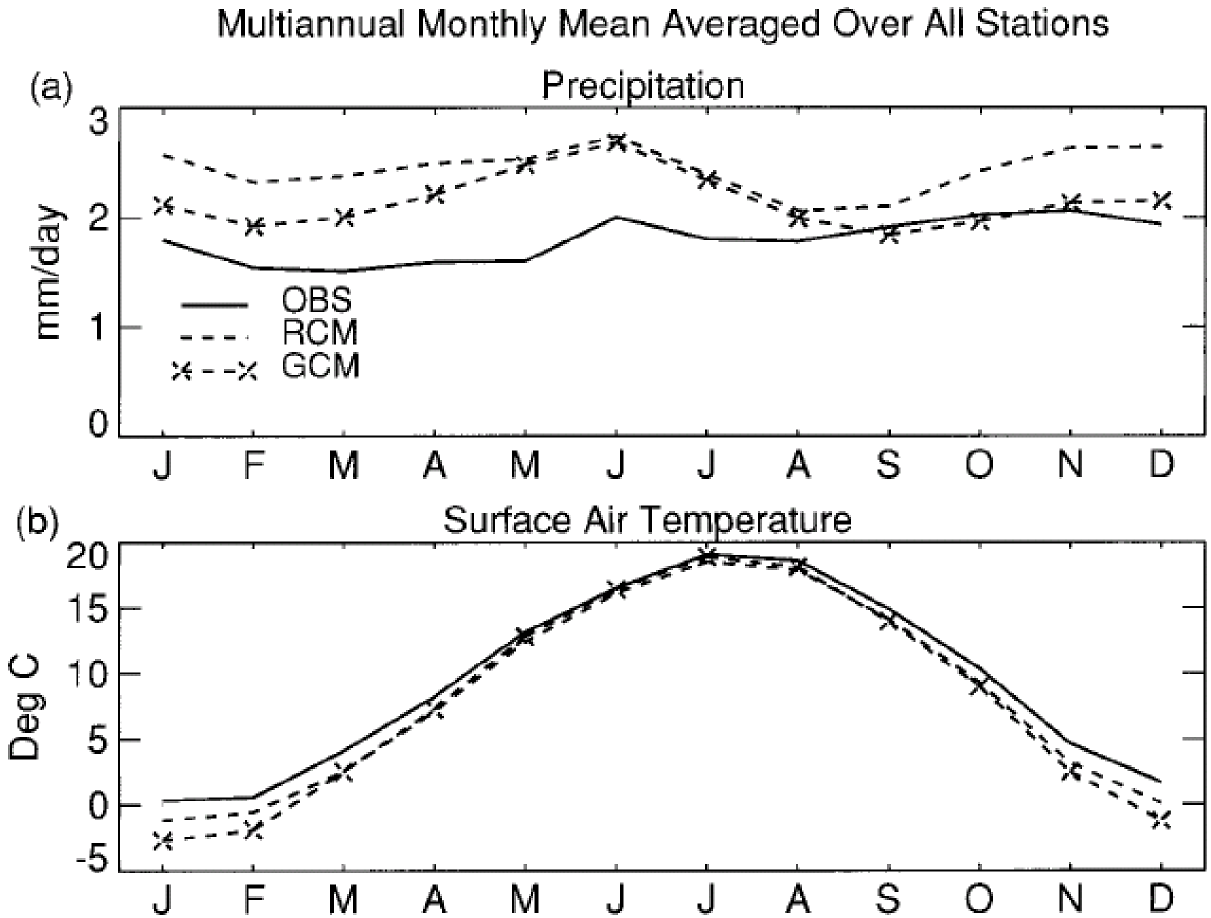


FIG. 2. Multiannual monthly means for 1983–93 (Jun–Dec), 1984–94 (Jan–Feb), or 1984–93 (Mar–May) of (a) precipitation (mm day^{-1}) and (b) diurnal mean surface air temperature (°C) averaged over all 976 observing stations for the observed station value (OBS) and the values simulated at the nearest regional model (RCM) and global model (GCM) land points.

Murphy , 2000

Statistical and Dynamical Downscaling

Both dynamical and statistical downscaling show similar skills to improve the large scale from CGMs.
They produce different predictions of local and regional climate.
SD methods are easy to use and need few computational resources while DD method are complex and require of lot CPU.
Both techniques neglect the interactions between global and regional scale.
SD generates a large number of realizations in order to assess uncertainties. On the other hand, DD provides consistent downscaled variable response to forcing.

Conclusions

- **Precipitation will decline in lower and mid latitudes and it increases in some regions such as in the part of tropics and high latitudes (2080-2099 relative to 1980-1999).**

- **Soil moisture content decreases in sub tropical and Mediterranean region. Runoff depends of the changes in precipitation; it is reduced in central American and Europe and increases in high latitudes.**

- **The groundwater recharge will decrease considerably in the South West Africa and North-Eastern Brazil.**

- **Statistical and dynamic downscaling were reviewed. Both techniques show similar skills to improve the large scale from CGMs.**