2. Climate change and water resources

A.Velmurugan and S.K.Ambast

Divison of Natural Resource Management, CARI, Port Blair

2.1 Introduction

Climate change has been receiving more attention of scientist, policy makers and common man with different perception. In recent times, several studies around the globe show that climatic change is likely to impact significantly upon water resource availability. In India, over the years demand for water has already increased manifold owing to several reasons. At present, changes in cropping pattern and land-use pattern, over-exploitation of water storage and changes in irrigation and drainage are modifying the hydrological cycle in many climate regions and river basins of India. But, Andaman & Nicobar islands located in the bay of Bengal has tropical humid climate with no major river system are more vulnerable to climate change and so its water resources.

The term climate change means “any significant in the statistical distribution of weather patterns over periods ranging from decades to millions of years”. It may be a change in average weather conditions or the distribution of events around that average. Climate change may be limited to a specific region or may occur across the whole Earth (IPCC, 2001). Since the beginning of the 20th century, there have been observed changes in surface temperature, rainfall, evaporation and extreme events which are considered as indicators of climate change.

The foremost concern of climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (UNFCCC). Green house gases (GHG’s) and aerosols are called as climate process drivers which results from anthropogenic activities, leading to perceived climate change indicators (Fig. 2.1). These changes negatively impact both natural as well as anthropogenic system which also affects the socio-economic development. Hence, it is imperative to develop proper mitigation and adaptation strategy with in developmental models at regional to global level for immediate adoption.

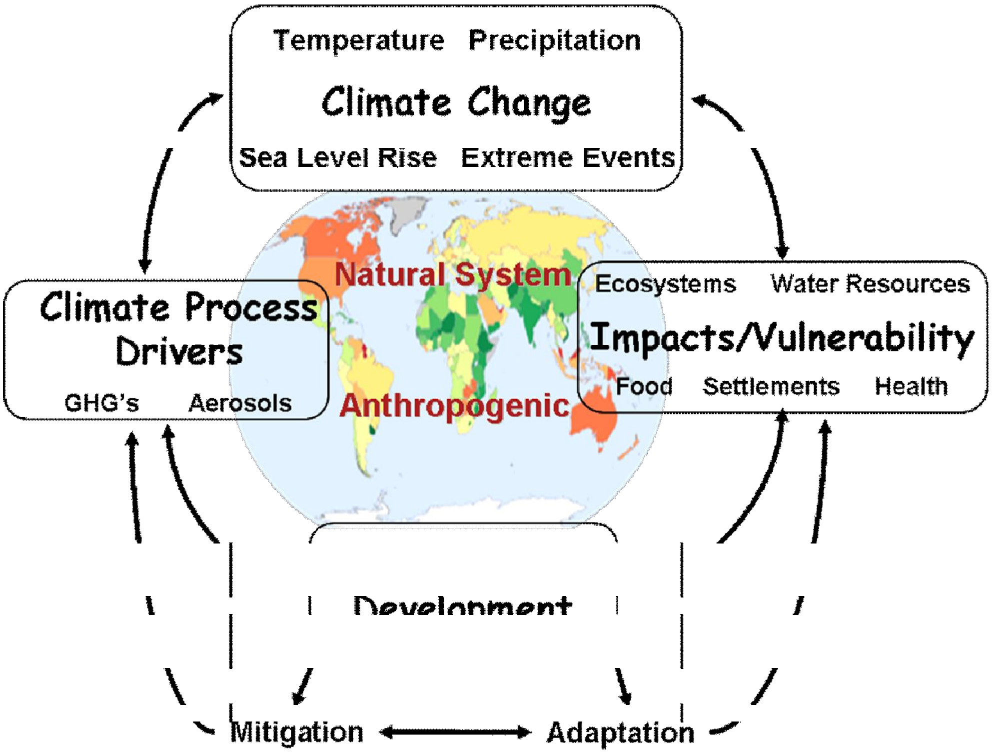


Fig. 2.1. Interlink between climate change drivers, responses and development

2.2 Drivers and indicators of climate change

Climate change phenomena are perceived through different indicators linked directly or indirectly to the emission of GHG's and aerosols as a result of anthropogenic activities. This can be evidenced from the fact that the atmospheric concentration of carbon dioxide has increased from about 280 parts per million by volume (ppmv) to about 369 ppmv. Similarly, other GHG's such as nitrous oxide, methane etc. This resulted in loss of atmospheric ozone, increase in global temperature by about 0.6°C, increase in climate disasters (Fig. 2.2) over the last few decades compared to the last two centuries.

The global mean sea level has risen by 10 to 20 cm. The average global surface temperature is projected to increase by 1.4–3°C from 1990 to 2100 for low-emission scenarios and 2.5–5.8°C for higher emission scenarios of greenhouse gases (under the new SRES 'Marker' scenarios) in the atmosphere.

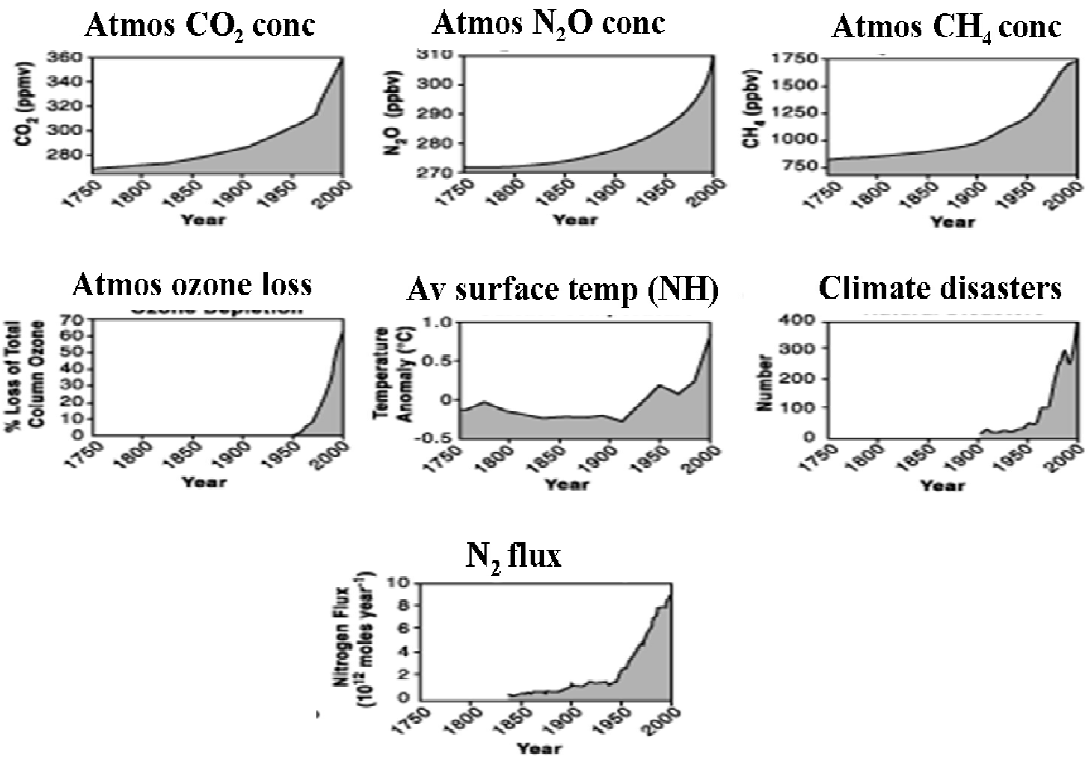


Fig. 2.2. Global GHG emission and climate change indicators

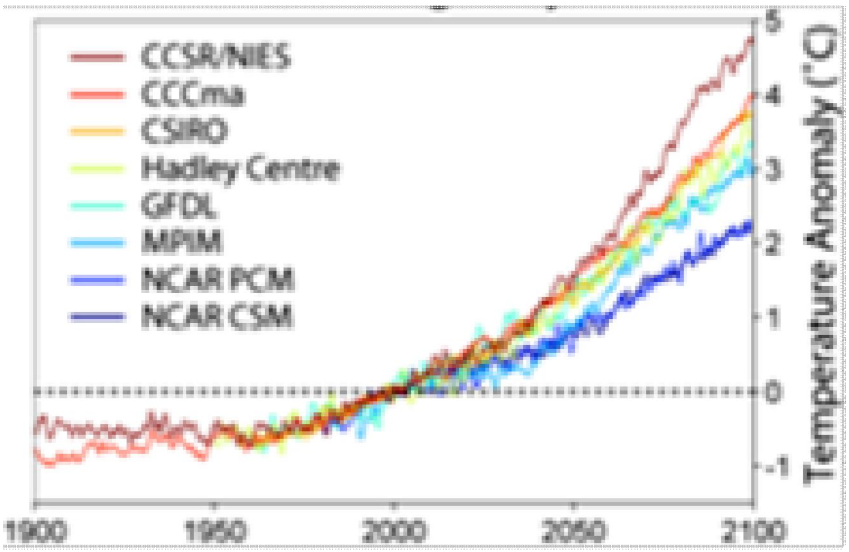


Fig. 2.3. Global warming projections (IPCC, 2001)

Calculations of global warming prepared in or before 2001 from a range of **climate models** under the **SRES A2** emissions scenario (Fig. 2.3), which assumes no action is taken to reduce emissions and regionally divided economic development.

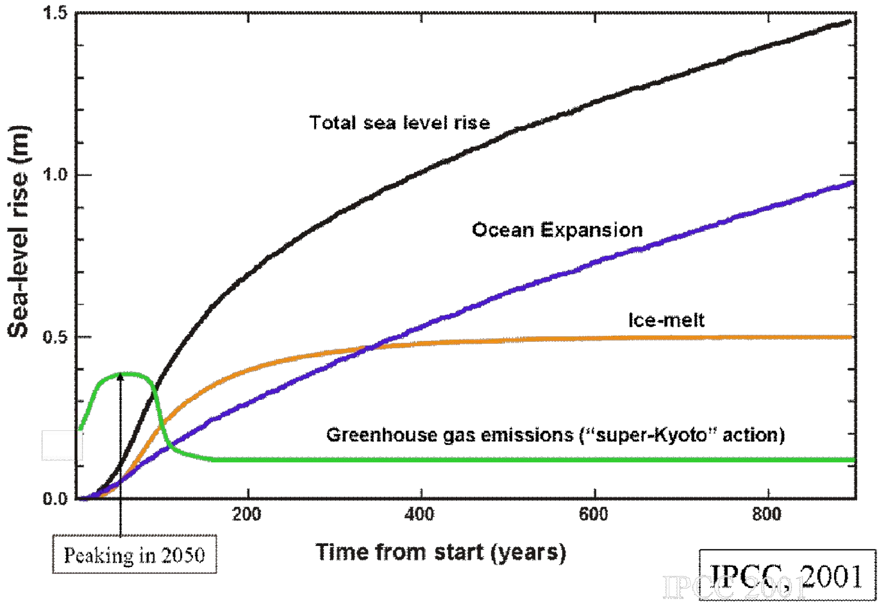


Fig. 2.4 Predicted changes in GHG's and sea level rise

Over the same period, associated rise in global mean sea level is projected between 9 and 88 cm. Even after a fall in green house gas emission it would take long time for the hydrological system to stabilize. The polar ice will continue to melt; ocean water will experience thermal expansion and together will results in sea level rise (Fig. 2.4). These changes will affect the **soil moisture, groundwater recharge and frequency of flood or drought episodes and finally groundwater level** in India and so in A&N islands.

2.2 Assessment of water resource potential and use

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. 97% of the water on the Earth is salt water, and only 3% is fresh water of which slightly over two thirds is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as groundwater, with only a small fraction present above ground or in the air. Water demand already exceeded supply in many parts of the world and as the world population continues to rise, so too does the water demand. Virtually all of the human uses require fresh water and biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems. Thus, the climate change not only affects water resources of a region or world but its ecosystem services as well leading to serious consequences on the existence of life forms in particular human beings.

2.2.1 Potential

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapo-transpiration and sub-surface seepage. The total quantity of water in any system at any given time is dependent on factors like storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates apart from precipitation. In A & N islands water is mostly stored for drinking water purposes, of course a fraction of the total annual precipitation. Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. In the island condition it is economically not feasible and technologically most challenging.

The groundwater resources have two components, *viz.* static and dynamic. The static fresh groundwater reserve is the aquifer zones below the zone of groundwater table fluctuation. The dynamic component is replenished annually, which has been assessed as 432 b.cu.m. According to the National Water Policy (2002), development of groundwater resources is to be limited to utilization of the dynamic component of groundwater. In A&N Island the total replenishable ground water resource is only 0.326 b.cu.m yr^{-1} though it is located in the high rainfall zone. Because, the topography, rainfall and prevalent rock formations which are unique to this Islands control run-off, occurrence of ground water, its recharge and movement. Throughout the course of a river, apart from the visible free water flow a substantial amount flows through sub-surface rocks and gravels that underlie the river and its floodplain called the *hyporheic* zone (Fig. 2.5). For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. But, in Island conditions this is not a significant quantity as there is no big river system coupled with undulating terrains. In coastal areas, human use of a sub-surface water source may cause the direction of seepage to ocean to reverse which can also cause soil salinization.

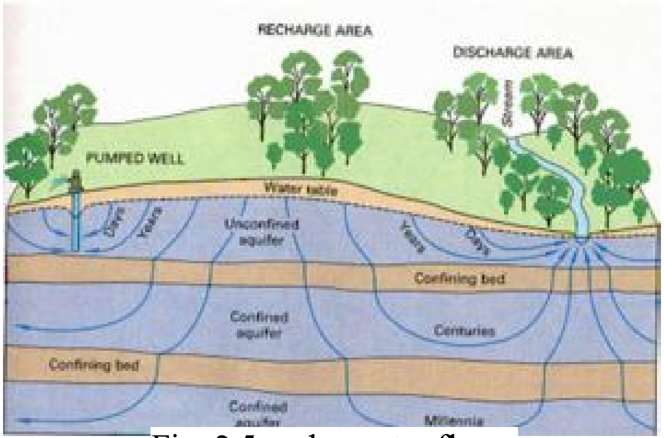


Fig. 2.5 under water flow

It is reported that the per capita water availability in A&N island is very high for the present (57,970 m3/year) and in the future (22,380 m3/year in 2051). The per capita water availability in all the islands is quite high in comparison to 1700 cu m national per capita water availability (less than 1700 cu m and 1000 cu m are termed as water stress and water scarce conditions) (Mall et al. 2006). However, these figures are deceptive as the amount of water available for harvesting in A&N islands is far below due to topography, forest land cover, high intensity of rainfall and other social reasons.

2.2.2 Uses of fresh water

Uses of fresh water can be categorized as consumptive and non-consumptive (sometimes called "renewable"). A use of water is consumptive if that water is not immediately available for another use. Withdrawal describes the removal of water from the environment, while consumption describes the conversion of fresh water into some other form, such as atmospheric water vapor or contaminated waste water. The major portion of fresh water (69%) is used for irrigation and a small portion (8%) is used for drinking water. In recent years, the competition for water resources is much more intense because of ever growing population and industrial need.

The percent land irrigated in A&N Island through canals and river is negligible when compared to the main land India due to climatic and physiographical limitations. The present irrigated area (Economic Survey of A&N islands, 2007-08) in A&N islands is 409.2 ha by pond, 985.5 ha by Nallah and 116.5 ha by wells, which is less than 5 percent of the cropped land excluding rainfed paddy area. Therefore, for the successful development of commercial agriculture especially vegetable cultivation needs proper water resource development for irrigation. Despite the fact farmers to a limited extent are utilizing stream water by constructing small check dams and even gravity fed direct flow into the field.

Aquaculture is a small but growing activity; freshwater commercial fisheries may also be considered as agricultural uses of water, but have generally been assigned a lower priority than irrigation. Industrial activities are very negligible in these islands; however there is a increase demand for fresh water from the tourism sector which is expected to increase in the coming years. The presently existing hydrological reservoirs of Andaman islands are mostly cater to the needs of drinking water, which depends on the monsoon.

2.3 Predicted changes in climate change indicators

Review of past and present trends of climate and climate variability indicates that temperatures have been increasing by as much as 0.1°C per decade, and sea level has risen by 2 mm yr^{-1} in regions in which small island states are located. Analysis of observational data for these regions suggests that increases in surface air temperatures have been greater than global rates of warming (e.g., in the Pacific Ocean and the Caribbean Sea regions). Observational evidence also suggests that much of the variability in the rainfall record of Caribbean and Pacific islands appears to be closely related to the onset of El Niño-Southern Oscillation (ENSO). However, part of the variability in these areas also may be attributable to the influence of the Inter-Tropical Convergence Zone (ITCZ) and the South Pacific Convergence Zone (SPCZ). It is acknowledged however, that for some small islands it is difficult to establish clear trends of sea-level change because of limitations of observational records, especially geodetic-controlled tide gauge records.

The use of the state-of-the-art coupled atmosphere-ocean general circulation models (AOGCMs) to estimate future response of climate to anthropogenic radiative forcing suggests an enhanced climate change in the future. Several AOGCMs have been analyzed for the Atlantic, Pacific, and Indian Ocean regions and the Caribbean and Mediterranean Seas. The outputs from these models indicate general increases in surface air temperature for the 2050s and 2080s and an increase in rainfall of about 0.3% for the 2050s and

0.7% for the 2080s for the Pacific region. However, a marginal decline in rainfall is projected for the other regions, with a possible reduction of water availability. The diurnal temperature range is projected to decrease marginally for the regions of the small island states for both time horizons.

Climate models predict an increase in annual mean surface air temperature over India and more prominently the arid tracts of Rajasthan. The changes are minimal in regions close to the equator as in the case of Nicobar group of islands but significant increase in annual mean surface air temperature is expected in the northern part of Andaman islands (Fig. 2.6). Similarly, climate models predict an increase in precipitation by –24 to 15% over India, but regional changes may be different. Studies on inter-annual and long-term variability of monsoon and annual rainfall have indicated that variation in rainfall for the subcontinent is statistically significant. In A&N islands upto 10 – 20% change in rainfall is expected (Fig. 2.7).

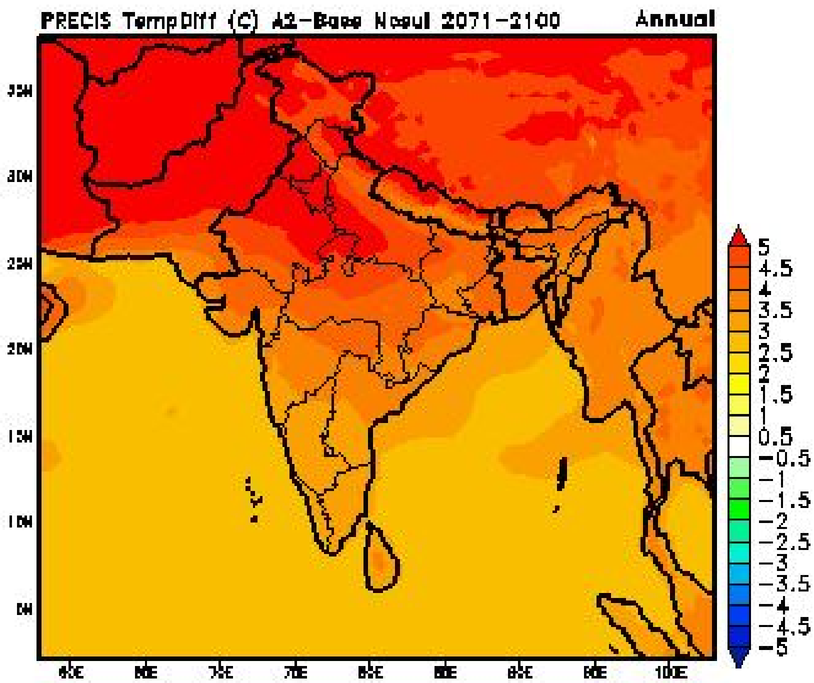


Fig. 2.6 Changes in annual mean surface air temperature (°C) for 2071-2100 relative to baseline (1961-1990)

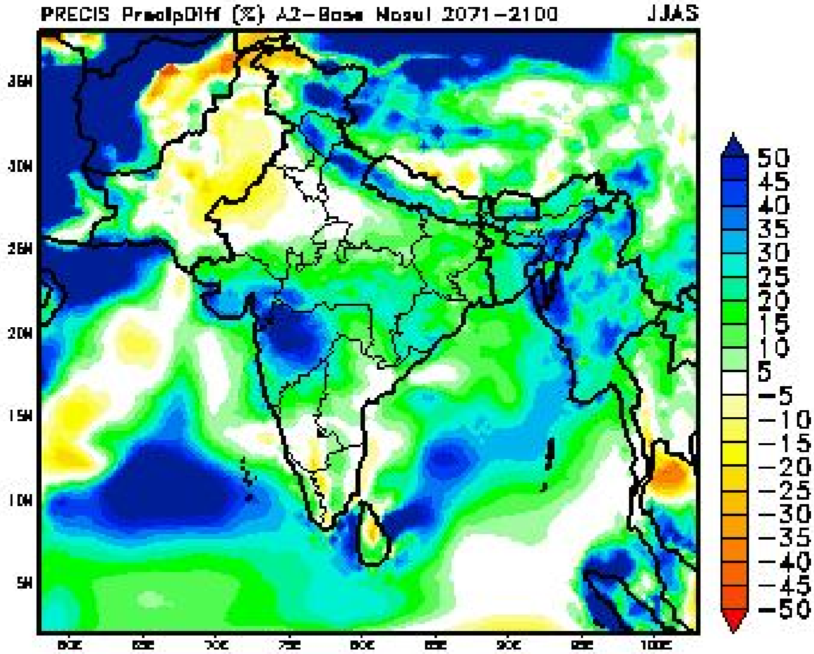


Fig. 2.7 Changes in rainfall (%) for the period 2071-2100 relative to baseline (1961-1990)

The most significant and immediate consequences for small island states which are applicable to A&N islands are,

- Changes in sea levels,
- Modified rainfall regimes,
- Soil moisture budgets,
- Prevailing winds (speed and direction) and
- Short-term variations in regional and local patterns of wave action.

Besides, owing to their coastal location, the majority of socioeconomic activities and infrastructure and the population are likely to be highly vulnerable to the impacts of climate change and sea-level rise (IPCC, 2001).

2.4 Interlink between climate change and water resources

Climate change can influence moisture content of the atmosphere, and its sources and sinks which are shown in Fig. 2.8. A warmer climate will accelerate the hydrologic cycle, altering rainfall, magnitude and timing of run-off. Warm air holds more moisture and increase evaporation of surface moisture. With more moisture in the atmosphere, rainfall and snowfall events tend to be more intense, increasing the potential for floods. However, if there is little or no moisture in the soil to evaporate, the incident solar radiation goes into raising the temperature, which could contribute to longer and more severe droughts (Trenberth, 1999). Therefore, change in climate will affect the soil moisture, groundwater recharge and frequency of flood or drought episodes and finally groundwater level in different areas. A number of studies have been reported in the literature to assess the impact of climate-change scenarios on hydrology of various basins and regions (Roserberg et al. 1999; Mirza et al. 2003 and Allen et al. 2004).

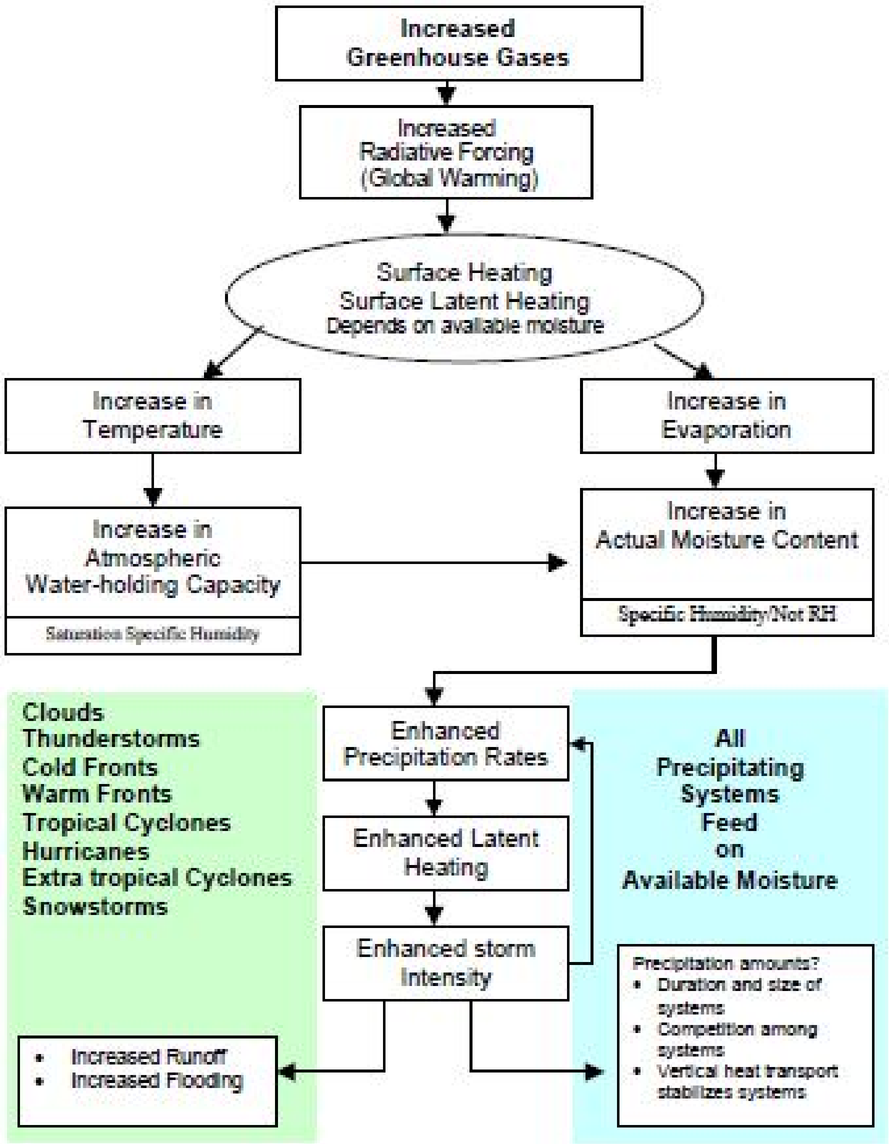
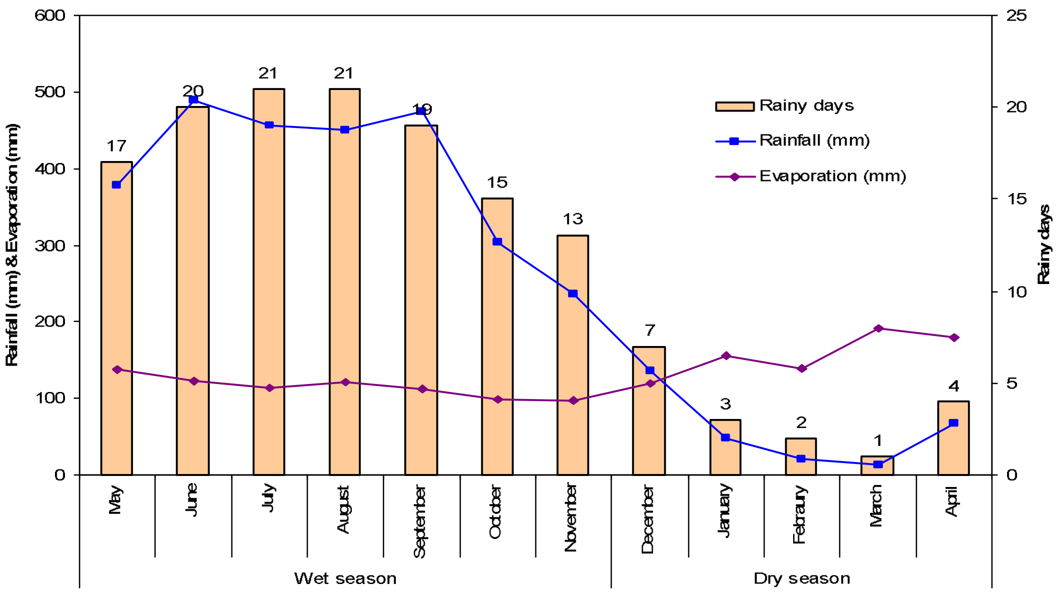


Fig. 2.8 Conceptual model of the effect of greenhouse gases on the hydrologic cycle and climatic extremes (Trenberth, 1999)

Andaman & Nicobar Islands receive an average annual rainfall of about 3180 mm of which maximum rainfall is received during southwest monsoon season (Fig. 2.9). The relative humidity (RH) varies from 68 to 86% and the maximum and minimum temperature is 32 and 22 °C respectively.



Wet – July to October ; Dry – Nov / Dec. to April; Av. Rainfall: 3074 mm

Fig. 2.9 Rainfall and evaporation in A & N islands

In spite of located in the high rainfall zone the Island suffers from moisture stress and poor crop harvest due to the erratic nature of rainfall the intermittent dry spells during the monsoon. A surplus of about 1530 mm rainwater from mid-May to mid-December and a deficit of about 610 mm are experienced during January-April. Nearly 75 percent of the rainfall received in the islands is lost due to undulated terrains, steep slopes, porous soil stratum and its proximity to the sea. As rainwater is the only source of the fresh water availability, its harvesting, storage and recycling forms the most important strategy for natural resource management in these islands.

An extreme event of flood or drought over the entire country or a smaller region constitutes a natural hazard. Hence, variation in seasonal monsoon rainfall may be considered a measure to examine climate variability/change over the Indian monsoon domain in the context of global warming. In 124 years, probability of occurrence of drought was found maximum in west Rajasthan (25%) followed by Saurashtra and Kutch (23%), however, with respect to A&N islands it is estimated to be 13% by Sinha Ray and She Wale (2001).

Water resources will come under increasing pressure in the Indian subcontinent due to the changing climate. Presently, more than 45% of the average annual rainfall, including snowfall in the country, is wasted by natural runoff to the sea. It is observed that in Andaman and Nicobar islands over the years the total number of rainy days is increasing and the same is decreased during the crop season. This needs to be analysed further, to understand its effect on the water resource availability especially surface and ground water resource. Rainwater-harvesting schemes are now being implemented in the country to minimize this run-off loss based on present rainfall scenarios over the country, to increase groundwater levels. However, for the success of these schemes it is necessary that we focus on how the possible climate change will affect the intensity, spatial and temporal variability of the rainfall, evaporation rates and temperature in different agro-climatic regions and river basins of India.

Gosain and Rao (2003) projected that the quantity of surface run-off due to climate change would vary across the river basins as well as sub-basins in India. However, there is general reduction in the quantity of the available run-off due to increase in ET on account of increased temperature or variation in the distribution of rainfall. As a consequence, Andaman and Nicobar islands will be experiencing high ET as it is very close to the equator and decrease in surface water resources. The analysis has revealed that climate change scenario may deteriorate the condition in terms of severity of water scarcity especially in dry months and intensity of floods during rainy season in various parts of the Islands.

Groundwater has been the mainstay for meeting the domestic needs of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. Around two-fifths of India's agricultural output is contributed from areas irrigated by groundwater. But in A&N Island ground water from deep well is not practiced, however, the shallow wells supply water to both domestic and agricultural purpose. In A&N island the total replenishable ground water resource is low (0.326 b.cu.m/yr) and in which the majority of them is used for agricultural activities especially vegetable crops (Table 1). The level of development is negligible and hence, with the increasing dry spells and less number of rainy days may affect vegetable production particularly in the elevated areas where ground water potential is low.

Table 2.1. Groundwater resource of Union Territories, India (b.cu.m/yr)

Union territory	Total replenishable GW.resource	Domestic, industrial and other uses	Availability for irrigation	Net draft	Balance for future use	Level of ground water development
A & N Islands	0.326	0.013	0.313	Neg.	0.313	Neg.
Chandigarh	0.030	-	-	0.025	-	
Dadra & Nagar Haveli	0.042	0.006	0.04	0.005	0.031	12.81
Daman & Diu	0.013	0.002	0.01	0.008	0.003	70.00
Lakshadweep	0.002	-	-	0.007	-	-
Puducherry	0.029	0.004	0.02	0.116	0.00	-
Total UT	0.442	0.025	0.384	0.160	0.348	

Source: Mall et al., (2006)

In Car Nicobar and other Nicobar groups of islands particularly in Car Nicobar, in the coastal plains the soils are very shallow (Fig. 2.10). Close to the coast, only few inches of productive top soil is found and because of its proximity to the sea and coral base, it is difficult to store the rainwater.

The dry spells are expected to increase and together the situation may lead to occasional / periodic agricultural drought. As a result, even sustaining the present level of production and productivity of plantation crops in particular coconut and arecanut will be difficult.

Fig. 2.10 Nature of soil and substrata in the coastal plains at Car Nicobar

In addition to this, drying of surface flow during summer month may severely affect the water yield in the well. With the combination of sea surge and storm is expected to affect the coastal water resources both for domestic and agricultural use.

2.5 Island Agriculture: Overall Impact of Climate change

Like many other Island nations, A&N islands are small physical size, relative isolation and are surrounded by large expanses of ocean; limited natural resources; proneness to natural disasters and extreme events. These features serve to increase their vulnerability to projected impacts of climate change.

In many countries, water is already in short supply because islands rely heavily on rainwater from small catchments or limited freshwater lenses. Arable land for crop agriculture often is in short supply; thus, the likely prospect of land loss and soil salinization as a consequence of climate change and sea-level rise will threaten the sustainability of both subsistence and commercial agriculture in these islands. Because water resources and agriculture are so climate sensitive, it is expected that these sectors also will be adversely affected by future climate and sea-level change. Although climate change is not expected to have a significant impact on world fisheries output, it is projected to have a severe impact on the abundance and distribution of reef fish population on the islands. The overall impact of climate change on water resources which directly or indirectly affects the followings:

- Increase in the potential evaporation which is related largely to increases in the vapour pressure deficit resulting from higher temperature (GCM simulations of climate).
- Loss of agricultural land either due to prolonged dry spell, water logging or coastal salinity
- Salinization of groundwater resources due to sea level rise
- Decrease in the availability of fresh water for drinking and irrigation
- Crop losses associated with extreme rainfall events

It is recognized that prudent and integrated water resources development and management for optimum and sustainable water utilization is an important and urgent issue to be taken up seriously, even without the occurrence of climate change impact.

2.6 Conclusion

So far the climate change predictions clearly points to the increase in air and sea surface temperature, sea level rise and variation in the rainfall pattern. But, large variation exists in terms of spatial impacts and accuracy of prediction due to paucity of quality data. Hence, it is vital to accurately assess the need and supply of water resources in various regions and develop technologies for sustainable development of surface water and groundwater resources within the constraints imposed by climate change. In view of the perceived climate change and its impacts on the Island water resource, the following points should be seriously addressed to adapt to the changing situations.

- The changing patterns of rainfall, i.e. spatial and temporal variation and its impact on run-off and aquifer recharge pattern should be studied.
- Proper analysis and understanding of the global and regional sea-level rise.
- Sea-water intrusions into costal aquifers and agricultural land.
- Determine vulnerability of regional water resources to climate change and identify key risks and prioritize adaptation responses.
- Evaluate the efficacy of various adaptation strategies or coping mechanisms that may reduce vulnerability of the regional water resources.

Though some climate change predictions are available for Andaman & Nicobar islands the observational net work facility for data collection has to be strengthened. Further research is required to address some of the important vulnerability issues associated with the present and potential future hydrological and ecosystem responses due to climate change.

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