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Awareness on impact of climate change in agriculture, a comparative study of chidambaram agricultural area by using educational global climate model software and weather research and forecasting model

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Abstract

Chidambaram, a semiarid region is subjected to high climate variability and sensitivity. In Chidambaram 1376 people comprising 5 per cent were involved in agricultural sector activities. In spite of the environmental confrontation primary agricultural sector consists of local and regional marketing, with paddy being the primary traded product, accompanied by cereals, black gram, pulses and sugarcane. Interdisciplinary study has been undertaken as climate and agriculture are interrelated processes; both take place on a global scale. The study area has been explored at local scale, by means of interviewing several farmers and interpreted by using the advanced weathering station established by Annamalai University. In order of broad scale understanding, advanced meteorological Meta data have been collected from the National atmospheric research lab, which relates the study to the national scale. At last all the processed climate data, comprises using, Anemometer, Sunshine recorder and sophisticated equipments are used as a feed data in Educational global climate model software. The turnout presents a substantial rise of carbon dioxide and noticeable amount of temperature change over a certain period. Even carbon dioxide levels would also have effects both detrimental and beneficial, on crop yields. This study aims to examine the impact of climate variables on agriculture and bring out the awareness of the farmers who are quitting from their agricultural activities due to this correspondence of ill effects and helps to sustain their life of human beings for present and future generations too.

Keywords: Climate Change, Crop Yield, Educational Global Climate Model, High Performance Computing, Weather Research and Forecast Model.

Introduction

The climate is one of the main determinants of agricultural production. There is significant apprehension about the effects of climate change and its variability in agricultural production throughout the world. The Climate change is any change in climate over time that is attributed directly or indirectly to human activity which alters the composition of the global atmosphere. In addition to natural climate variability observed over comparable time periods (IPCC, 2007). Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have a significant impact on crop yields and production. Of course the industrial revolution in the western countries was rapidly utilized the fossil fuels, on the other side the natural buffering system for climate change, forests were destroyed indiscriminately for want of fuel, fodder and timbers in the developing countries. These factors were intensified by the human activities in the past 250 years, which had tremendous impact on the climate system[1]. According to the IPCC the greenhouse gas emission could cause the mean global temperature to rise by another 1.4° C to 5.8° C. Already the symptoms of climate change were observed at a faster rate in the arctic and under arctic regions through melting of the frozen ice which have the danger of submergence of the coastal zones. In the case of the inland water source, there is tremendous change in both surfaces as well as ground water due to erratic rainfall and occurrence of frequent droughts[2,3]. Anthropogenic activities are the main reasons for Climate Change. Industries, transportation, generation of power are the main reasons for the increase in temperature. Agriculture, forestry and fisheries are sensitive to Climate Change impacts on the one hand, and are also contributing to emission on the other. Agriculture accounts for 13.5 percent of global greenhouse gas emissions from fertilized soils, biomass burning, rice production as well as manure and fertilizer production[4]. According to Intergovernmental Panel[5] on Climate Change (IPCC) mitigation is defined as an anthropogenic intervention to reduce the sources or enhance of the Greenhouse Gases[6]. On other hand climate adaptation refers to the ability of a system to adjust to Climate Change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities or to cope with the consequences[7]. To meet the challenges posed by Climate Change on the agricultural system, Indian Council of Agricultural Research (ICAR) has accorded high priority in understanding the impact of Climate Change and developing adaptation and mitigation strategies through its network research program, National Project on Climate Change

(NPCC). Its main objectives are to identify the region experiencing extreme Climate Changes, developing methodologies for assessing the impact of Climate Change on agricultural productivity and suggesting suitable intervention for reducing the impact of Climate Change. Climate change may exacerbate the impacts and thus limit agricultural production. Notwithstanding the challenges in the agriculture sector, animal Husbandry, including fisheries sector, which together account for a quarter of total agriculture and allied activities GSDP, provides opportunities for livelihood diversification in this sector. Any impact on agriculture and allied sectors will exert cascading effect on secondary and tertiary sectors. At present, though there is no systematic study to assess the direct and indirect effects of climate change on agriculture and allied sectors, this sectoral plan will enable the State to assess the vulnerability of the State to climate risks, prioritization of research and development issues and effective decision making to reduce risks through adaptation[8].

Study area: Chidambaram, known as a temple town of Tamilnadu was chosen as the study area to perform the analysis. The town nearly lies at 11.3982° N, 79.6954° E latitude and longitude (Figure-1), with a geographical area of 4.8 km^2. The semi arid, suburban town is situated at the south-east coastal shoreline of the country. Despite of not being the primary source of income for local people, agriculture still manages to improvise considerable impact to the gross economy and enriches the state's Gross Domestic Product (GDP) by 7%. Currently, 59% of the total geographical area (i.e 217331 hectares) of Cuddalore district are under the consideration of the net cultivable area of food production, of which rice being the majority and comprises more than half of gross cropped area.

Methodology

Temperature projections: Maximum temperature: The study predicts maximum projection of temperature over the state of Tamilnadu on an average is 1.1^{0}C, by the years 2040, with respect to the baseline 2001 to 2016. Hence elaborative analytical study was undertaken in order to predict the district wise changes, which shows an impending temperature rise of 1.3^{0}C over the North western districts of Nilgiris, Coimbatore, Tiruppur and western parts of Dindigul District. On the other hand a minimum increase of around 0.7^{0}C seems to be observed towards the eastern parts of coastal districts, particularly over Kanyakumari, Nagapattinam, Tirunelvelli and Ramanathapuram, because of the sea breeze and other governing factors (Figure-2).

Minimum temperature: Irrespective of maximum temperature projection, minimum temperature may have an ensuing rise of 1.0^{o}C with reference to baseline 2001 to 2016. The same study was performed in micro scale to predict the district wise changes. It indicates minimal intervention over the western parts and close to the coast. Also the model indicates a pragmatic warming of ambient atmosphere by 1° to 1.50°C for the period 2010 to 2040. As per the software model indicates, probable rise in minimum temperature will be excessive in the case of central interior districts like Karur, Tiruppur, and Namakkal and will be moderate in southern districts like Kanyakumari and Tirunelvelli (Figure-2).

Instruments used in order to interpret: Primary instruments: A sophisticated weather station established by Annamalai University was utilized to explore the weather phenomenon at micro scale. Various primary instruments like rain gauge, soil thermometer, sunshine recorder, wind vane, anemometer etc. were used to set up the preliminary study (Figure-3).

Advanced instruments: Weather Observational Instruments enacted predominately viable for the accomplishment of the above study are such as Surface Flux Tower, Microwave Radiometer, Lightening detector, Electric Field Mill, Net Radiometer, Rayleigh Lidar, High Performance Super Computer, 50m automatic weather tower etc. (Figure-4)[11].

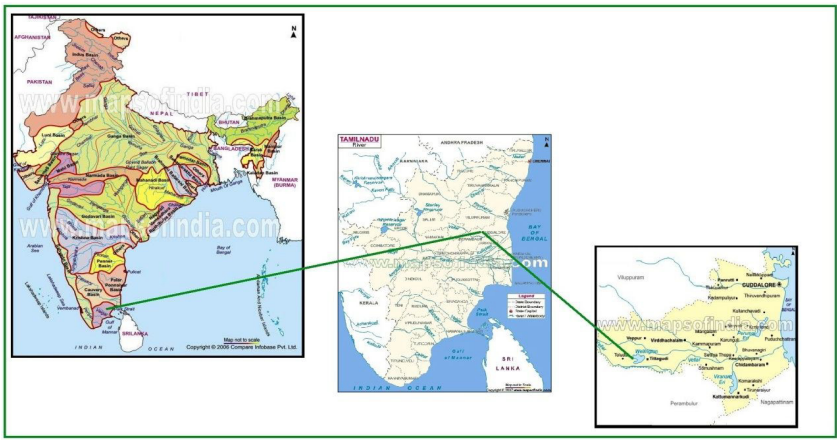

Figure-1: Location of the study area.

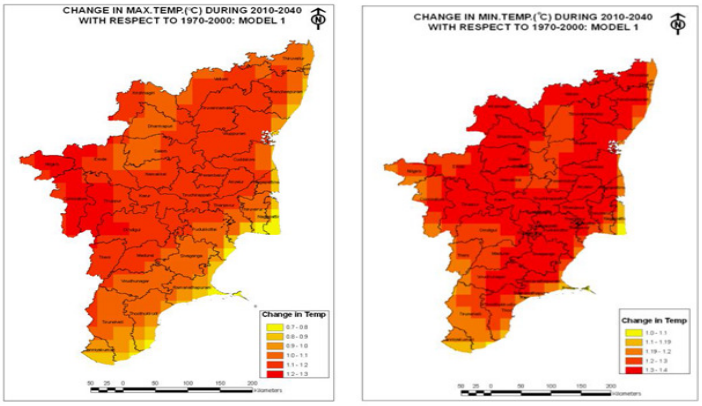

Figure-2: Change in maximum and minimum temperature (c) projections of 2040.

Figure-3: Various instruments of analysis and location of station in AU.

Figure-4: The instruments were used cordially to prepare the feed data for the HPC.

The various above mentioned instruments, their mode and range of working and capabilities against withstanding the fluctuations are shown in Figure-5.

Comparative studies by Educational global climate modeling software (EdGCM): EdGCM is an incorporated software module, which efficiently performs the process of monitoring, analyzing and predicting the climate change phenomenon, based on the real time data availability (Figure-6)[9].

Weather research and forecast model application: Various meteorological data were collected and analyzed through a high performance super computer in Linux system by means of WRF model for better understanding of the effect of meteorological parameters on climate change and finally on crop yield. The complex data processing and formatting procedure of WRF model is shown below in the Figure-7[12,13].

Results and discussion

A complex study was performed by HPC supercomputers through Weather research and forecast model which shows the following outputs (Figures-8, 9, 10, 11, 12 and 13).

The Education Global Model software performs the analysis by taking the above data as a feed and represents them in the form of digital output, which includes the temperature rise and differential CO_2 emission rates (Figure-14 and 15).

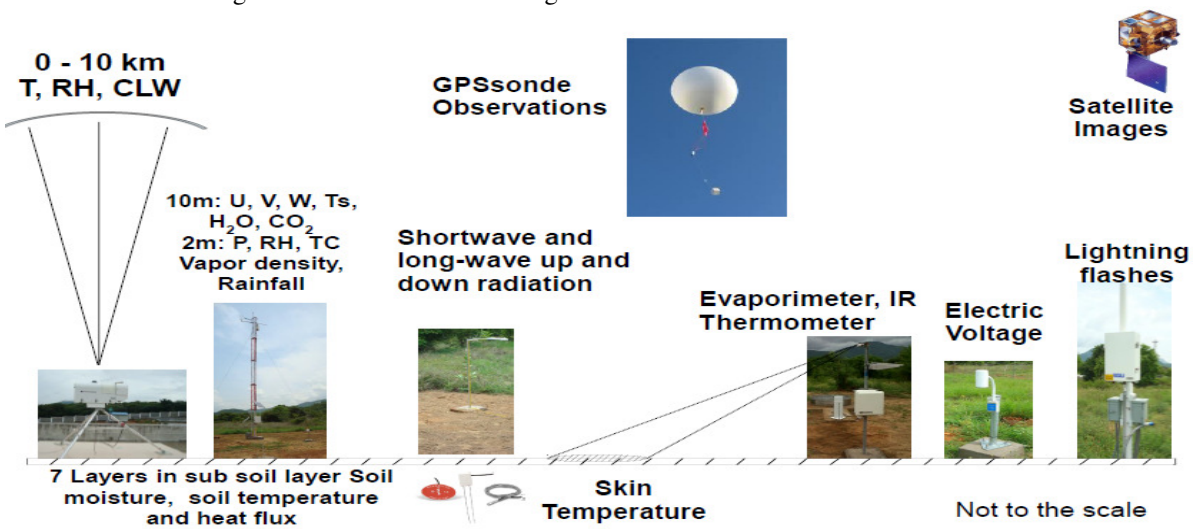

Figure-5: Observational facility for modelling activity.

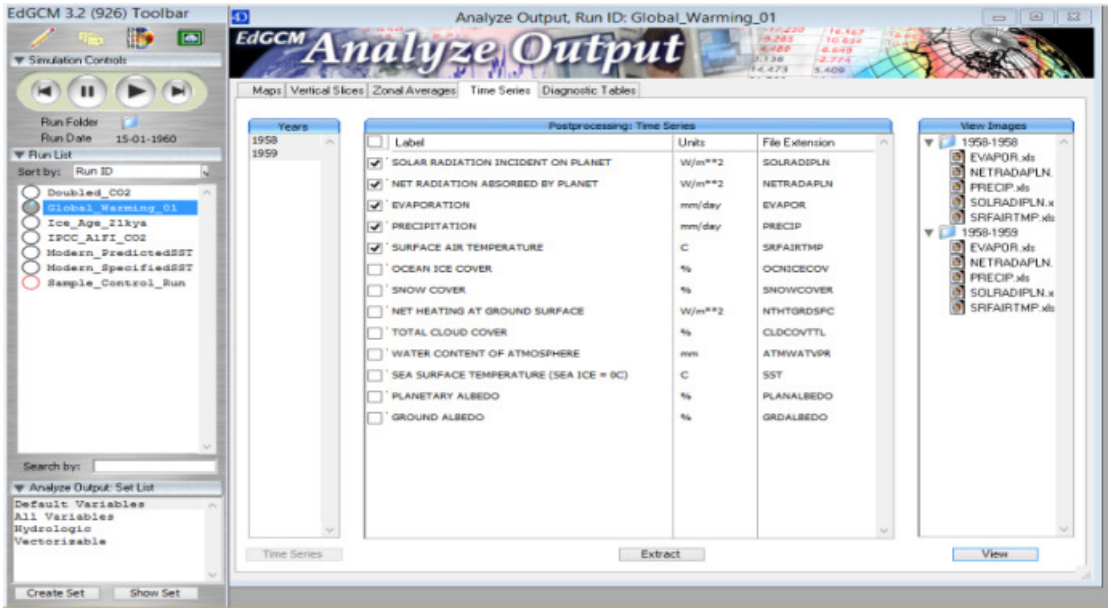

Figure-6: Software output sight.

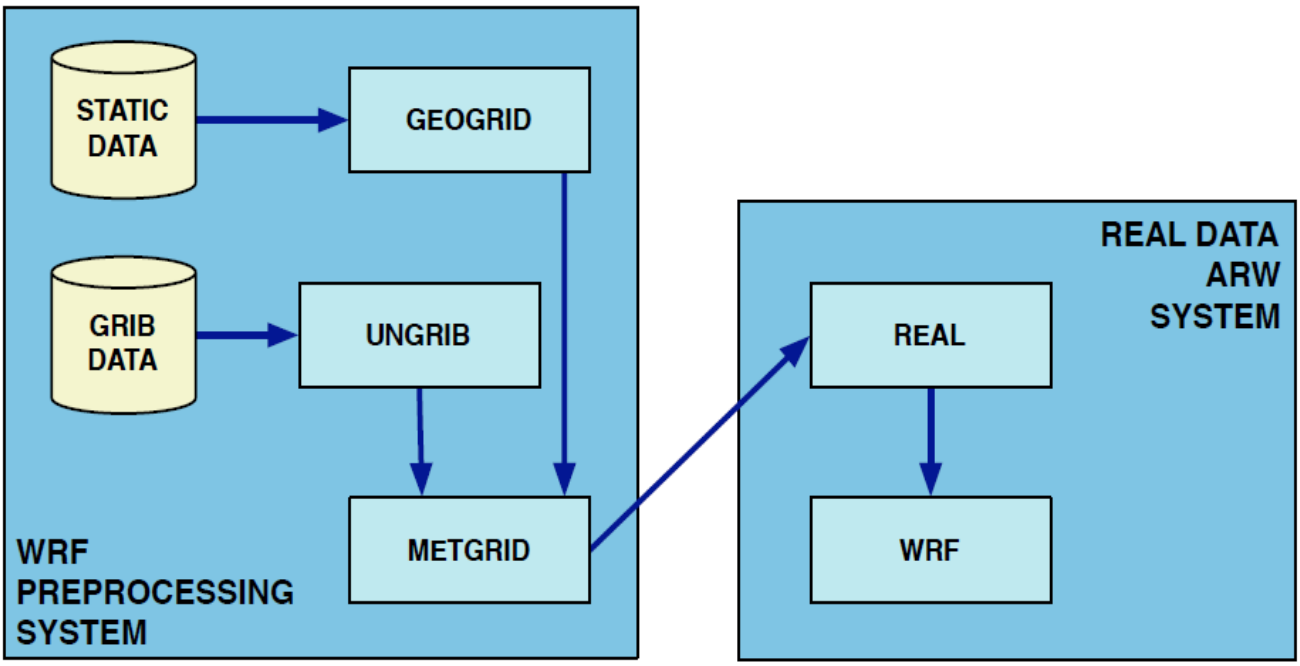

Figure-7: Work flow of WRF model.

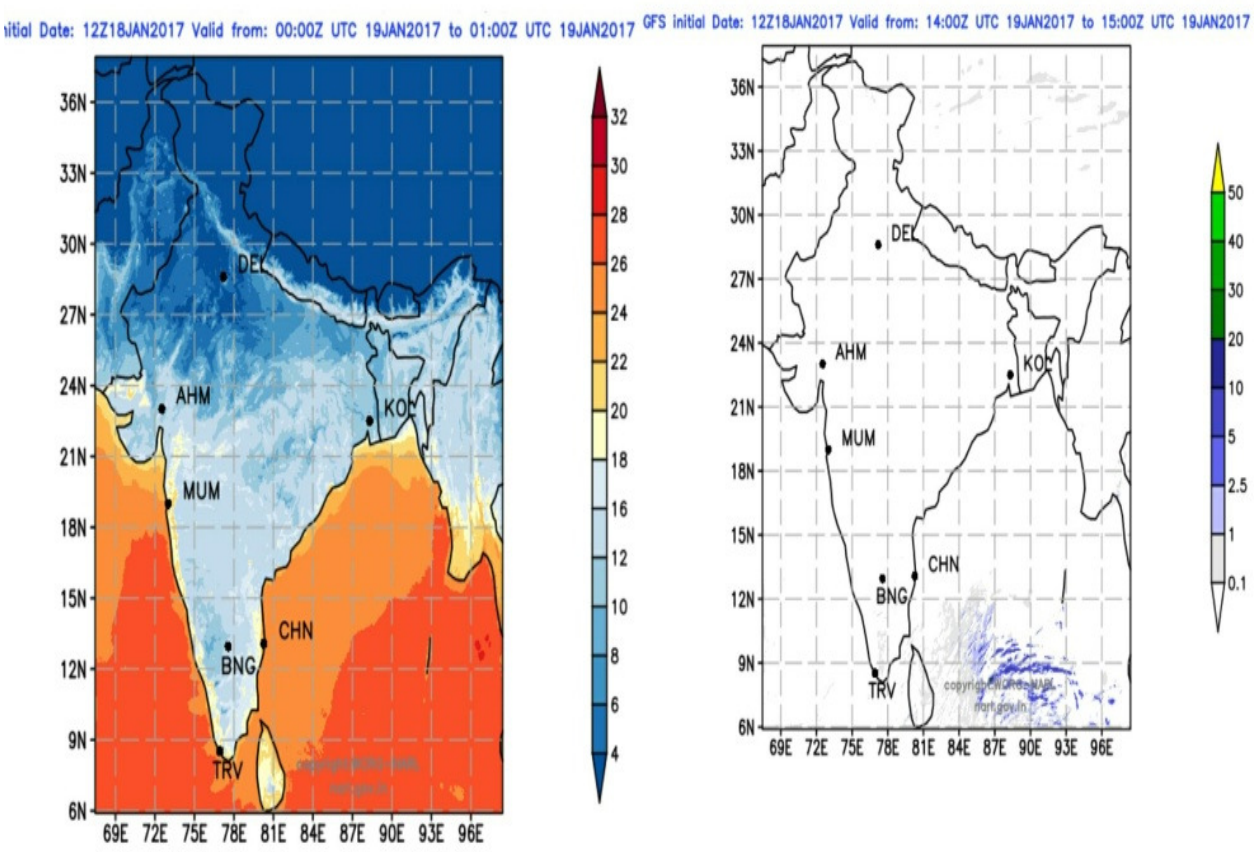

Figure-8: Surface temperature and Rainfall data.

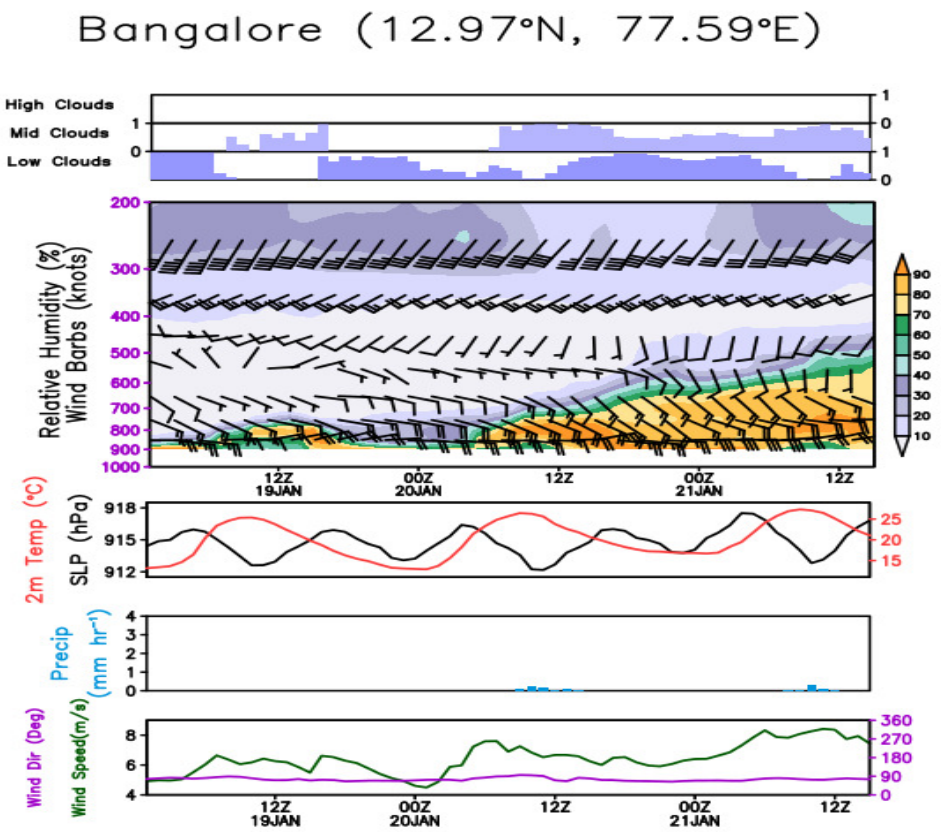

Figure-9: Meteograms for Bangalore.

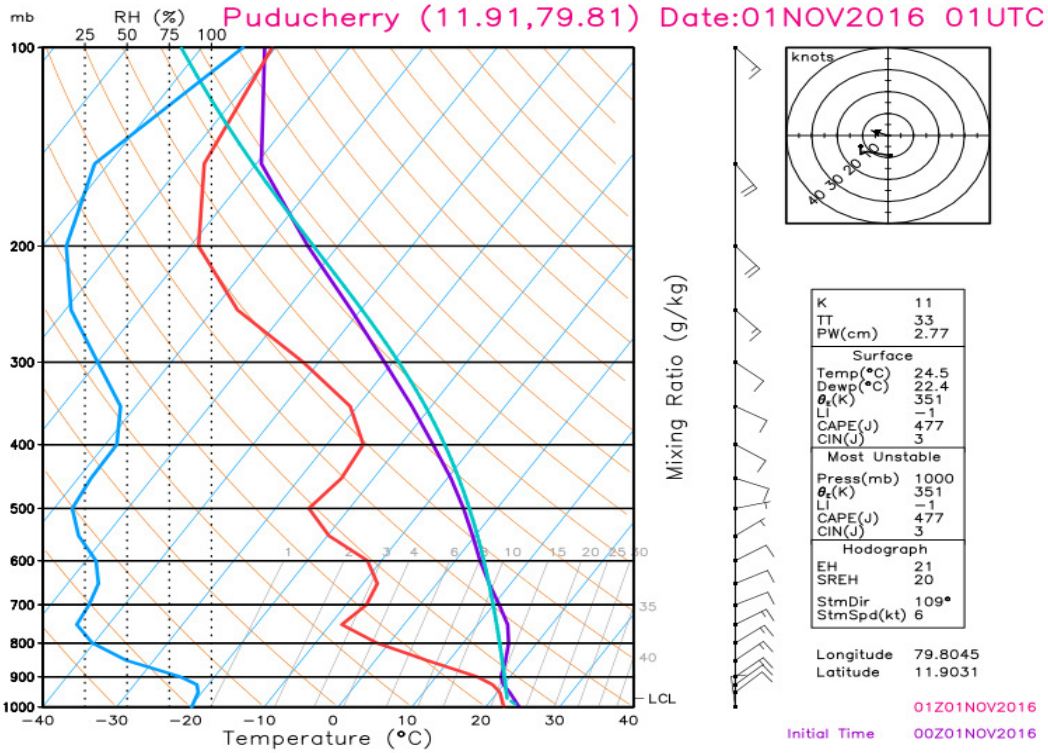

Figure-10: Tephigrams for Pondicherry.

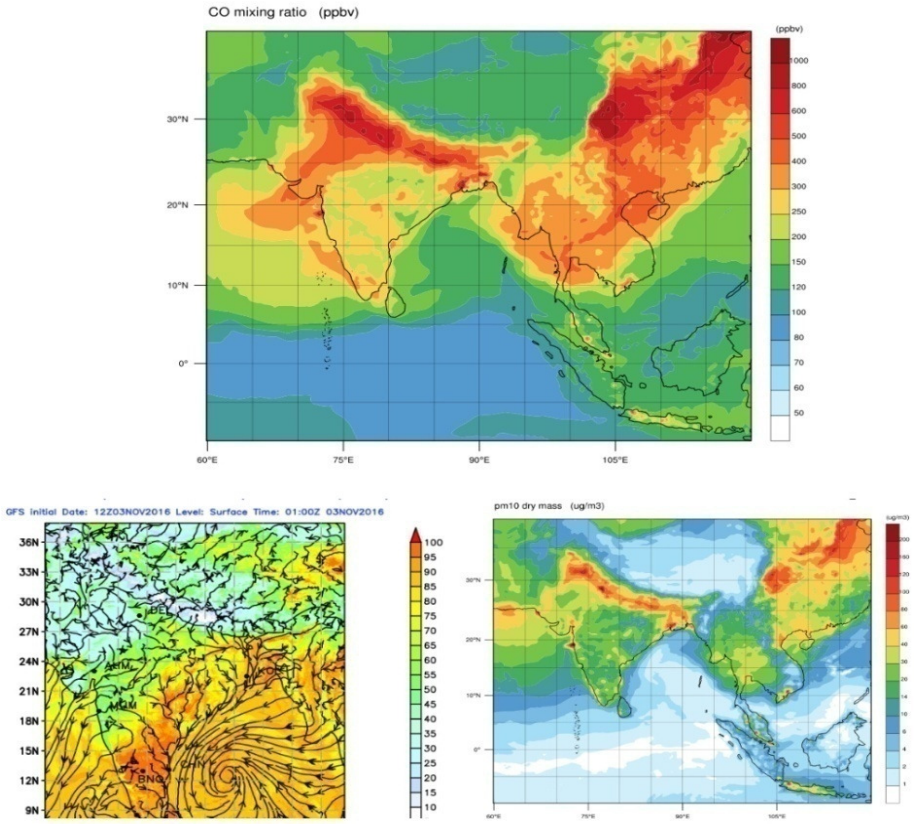

Figure-11: Mixing rate of CO, RH and PM10 analysis.

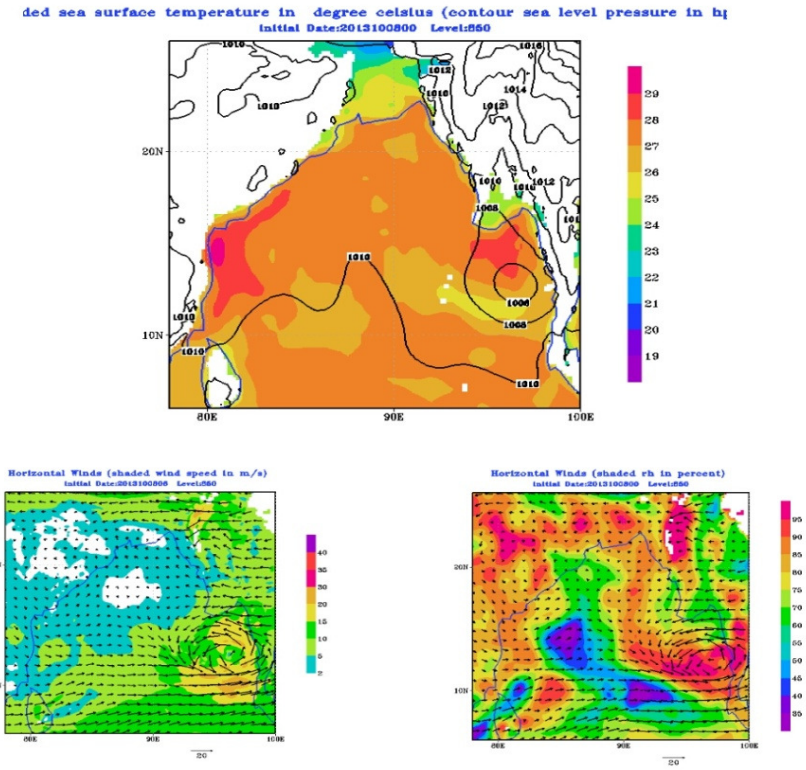

Figure-12: Relative humidity, Sea level Pressure, Wind speed.

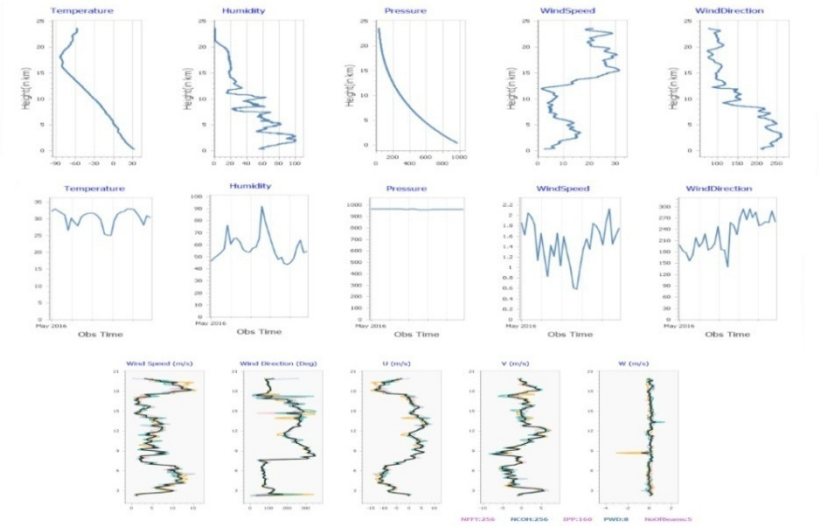

Figure-13: Change in various meteorological parameters with respect to height.

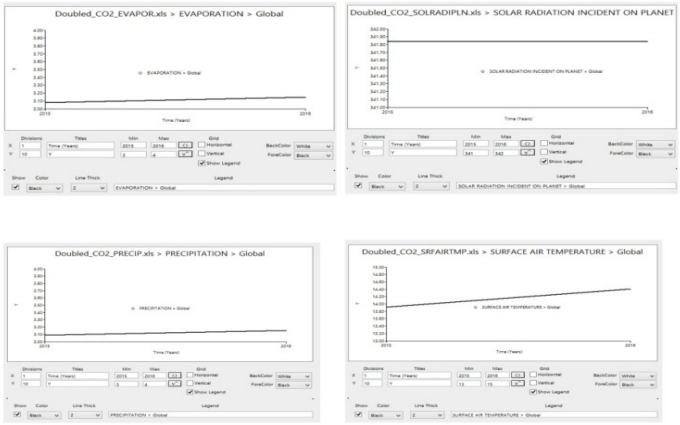

Figure-14: CO_2 emissions during 2015- 2016 concerning with various other parameters.

Figure-15: Global warming during 2015-2016.

Table-1: Analyzed weather data show the significant change.

Year: 2012	Temperature (˚C)		Wind velocity	Rainfall
Month	Maximum	Minimum		
JAN	29.3	21.0	3.0	011.7
FEB	30.5	21.3	3.4	000.0
MAR	33.4	23.3	3.5	010.0
APR	34.9	26.1	4.0	006.4
MAY	38.3	27.4	8.6	002.8
JUN	37.9	27.3	9.5	000.6
JULY	35.7	25.7	6.3	078.0
AUG	35.2	25.3	6.4	079.4
SEP	34.9	24.9	5.8	113.3
OCT	31.0	24.0	3.9	640.2
NOV	30.4	23.1	4.5	098.4
DEC	29.2	22.3	5.0	045.5
Total	400.7	291.7	63.9	1086.3
Mean	33.3	24.3	5.3	-
2013				
JAN	33.4	23.6	4.5	004.2
FEB	30.4	21.8	4.1	060.1
MAR	32.4	22.4	3.5	030.6
APR	35.8	25.6	4.7	000.0
MAY	38.2	27.0	6.5	043.8
JUN	36.1	26.5	7.3	021.4
JULY	35.6	25.8	6.6	042.8
AUG	33.7	24.3	5.2	201.6
SEP	33.0	24.4	4.7	144.9
OCT	32.9	24.5	3.3	120.4
NOV	29.1	22.9	3.9	298.9
DEC	28.0	21.1	4.0	222.8

Year: 2012	Temperature (˚C)		Wind velocity	Rainfall
Month	Maximum	Minimum		
Total	398.6	298.9	58.3	1188.5
Mean	33.2	24.1	4.8	-
2014				
JAN	28.4	20.9	4.4	007.2
FEB	29.6	20.3	2.7	025.8
MAR	31.6	21.9	2.9	000.0
APR	34.9	24.5	3.4	000.0
MAY	33.8	25.8	5.0	183.2
JUN	37.2	26.8	5.8	067.2
JUL	35.3	25.6	6.3	092.4
AUG	33.9	24.8	4.7	171.0
SEP	34.1	24.7	4.0	034.5
OCT	31.6	24.1	2.5	528.9
NOV	28.9	23.1	3.5	341.8
DEC	28.0	22.6	04.8	227.9
TOTAL	387.3	285.1	50	1679.7
Mean	32.2	237	4.1	-
2015				
JAN	28.7	21.2	2.5	022.8
FEB	29.6	20.8	2.5	000.0
MAR	32.3	22.9	1.9	000.0
APR	34.1	24.8	2.8	067.5
MAY	33.9	26.2	4.3	100.8
JUN	34.9	25.5	5.1	073.2
JUL	36.7	27.5	4.5	107.6
AUG	35.1	25.6	3.5	125.0
SEP	35.0	24.6	4.6	028.6

Year: 2012	Temperature (˚C)		Wind velocity	Rainfall
Month	Maximum	Minimum		
OCT	32.8	24.1	3.0	118.0
NOV	29.1	23.5	3.9	950.0
DEC	29.2	23.2	3.1	459.0
Total	391.4	289.9	41.7	2025.5
Mean	32.6	24.1	3.4	-
2016				
JAN	29.8	21.2	2.9	007.0
FEB	31.5	22.0	2.4	000.0
MAR	33.8	23.3	3.0	000.0
APR	36.5	26.1	4.7	000.0
MAY	36.1	26.4	5.0	124.8
JUN	35.1	25.8	5.1	055.0
JUL	35.3	25.4	4.5	041.8
AUG	35.8	24.8	5.1	167.2
SEP	34.3	24.9	5.8	086.6
OCT	34.2	25.2	2.5	052.5

Impact on crop production: In spite of being one of the most modernized and urbanized state of India, Tmailnadu posses 22% of its annual gross income from the basic agricultural and associated activities, but since last few years, this sector was subjected to the potential decrement, due to the high climate variability. According to the survey undertaken by the Department of Environment, Govt. Of Tamilnadu, this sector, which showed a susceptible rise of 15.28% during 2006-'07, faced a subsequent loss of 4.46% in 2007-'08 due to the ill effects of natural calamities on crop yield. Despite of the above consequences, still around 40% of the state population sustain on the basic agricultural activities for their livelihood. Hence, considering the above factors, a potential growth is mandatory, in order to meet the future requirements, as well as to hike up the standards of living for farmers. Though numerous and persistent hydro meteorological phenomenon such as droughts, extreme rainfall and cyclones is unstimulating for the agricultural aspect, the growth of the sector is also inhibited by other major governing factors, namely, water scarcity and declination in the cultivable land area, etc. A recent report reveals that the availability of the fertile land in Tamilnadu has declined from 33% to 31% of total land area within a period of one decade (i.e. 2001-2011). Apart from this, individual small scale land ownership, deterioration of soil fertility due to soil erosion & declination of soil nutrient, increase in cropping frequency to meet the recent demands and shortage of skilled workers besides unwillingness to work on the farms and pitiable implementation of crop management practices etc. suppress the expected growth in agriculture even further. The agricultural sector of the state has witnessed an optimum rise in crop yield during the year of 2001-'02 and subsequently utmost declination in the year of 2002-'03, due to extreme drought. Afterwards, in spite of taking many initiatives, the net sown area hasn't been able to be recovered. As far as the scenario of Annamalai University agricultural area (i.e. comes under the department of Agronomy) is considered, the total crop area of 258 hectares is irrigated and managed by sewage farming technique, by means of partially treated wastewater collected from several residential buildings under university premises. The recent study indicates the change in crop pattern and their yield over a period of one decade, which predicts that the Rainfed crops are the worst sufferer due to climate change susceptibility and various changes in crop yield values are tabulated in Table-2[10].

Table-2: Change in crop yields during past decade due to climate change in Chidambaram agricultural area

Crop varieties	2005-2006 (kg/ha)	2015-2015 (kg/ha)	Ultimate change (%)
Paddy	2887	2792	-3.3
Maize	1047	1334	+27.4
Wheat	1483	1461	-1.49
Ragi	432	518	+19.9
Pulse	268	261	-2.7

Conclusion

In order to achieve the objective of this work and to develop a monitoring based meteorological model, which can result in maximum crop yield, several observing parameters are crucial and has to be taken into account, to simulate satisfactory outputs namely, mitigate the problem of pests and harmful bugs in the region of interest, meteorological data collection and processing etc. The software module coined the idea of preliminary change in yield is influenced by baseline climate and the calibrated model predicts that the subsequent temperature rise of about 2.0^0C will result in major declination of mass production. Predominant detrimental effects could be observed in case of Rainfed crops. The experimental values indicate that predominant pessimistic change takes place in the case of paddy, wheat & pulse. The respective data are tabulated in Table-2. Climate Change and agriculture are inseparably linked globally, both affecting and influencing each other. Climate Change influences the crop yield and quality, fertility status of soil and may pose a serious threat to food and nutritional security. Talking about the current scenario the main confront for Indian agriculture is to mitigate prospective challenges in the form of climate variability and to get acclimatized to the extreme events without successive loss in yield and food security. Our study shows a potential temperature rise of 5.6^oF within 2060 & uncertainty in precipitation is over various climatic zones. The consequences of these changes may result in a need to adopt existing regulation with respect to environmental policy goals. Though the efforts are going on to develop strategies to mitigate the negative impact of Climate Change and research in new directions are being carried out, more emphasis is required to make sufficient investments to support Climate Change adaptation and mitigation policies, technology development and dissemination of information. Making possible of interlinking rivers from the northern to the southern India region to solve the problems of drought. Now, after taking all the probable reasons under consideration of the above study, a conclusion has been arrived that the greenhouse effect and global warming could be the most appropriate reason of climate change, which is accelerated due to anthropogenic activities. But in this regard, a practical remedial strategy of raising mangrove forest is suggested along the salt wetlands of coastal southern districts to offer protection for agricultural crops against the fiery effect of natural calamities like cyclone, and also to remove carbon dioxide from the air much more efficiently as well reducing the atmospheric temperature, thereby mitigating the growing threat of climate change. Several pilot scale mangrove forestation came into the scenario through the shoreline of the Cuddalore coastal region during the last few years, which shows a significant lapse in CO_2 level (Figure-16).

Figure-16: Artificially developed Mangrove by Marine Engg department of Annamalai University.

Future scope: In order to improve the understanding of all the meteorological parameters effect on crop yield, individual parameters can be monitored and analyzed. Water and nutrition management also could be undertaken to study, for better understanding of the growth pattern of crops.

Acknowledgement

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