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Study and Analysis of Surface Weather Parameters over Haryana Using ERA-15 Data (1979-93)

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ASBSTRACT Total atmospheric moisture content present in the atmosphere is less than 1% of total atmospheric composition. The atmospheric moisture variability accounts for nearly 10% variation in global hydrological cycle. The atmospheric moisture variability occurs in the form of cloud cover and hence in to the precipitation. A prior knowledge of cloud cover and the resulting precipitation will be significant for global hydrological cycle protection and planning. ECMWF Re-Analyses (ERA), ERA-15 assimilated the data sets of surface and upper air daily weather data of temperature (maximum, minimum), wind, cloud cover, precipitation, and evaporation. In the present study analysis of surface weather parameters, correlation of simulated cloud cover and precipitation, comparison of the precipitation during monsoon season over Haryana is considered. Also the simulated precipitation is compared with IMD observations. In addition the performance of the ERA-15 data sets of precipitation over Haryana 12-months of the year is evaluated. Temperature and dew point temperature patterns show 3-year cycle.

1. INTRODUCTION

Climate is an active factor in the physical environment for all the living beings. It influences on human welfare range from the immediate effect of weather events to complex responses associated with climatic changes. The modern advanced communication media that inform us almost daily of floods, droughts, hurricanes, heat waves or other disasters. Occurrence of these events leads to property damage, crop failures, famine and deaths the world over. Dire views of the climate failure or epoches, produce global heating or cooling, advance or recession of polar ice, changing sea level, expanding deserts and inevitable hunger. Climate change and its research have gained lot of momentum in recent years. From global it has been scaling down to regional or local concerns. In fact it makes an impetus to our planning and policies on decadal time frame. The analysis of influence of long-range climate factors on regional climate is to be given a fresh thought. Thus study of regional climatology variations in decadal time scales do possess an immense potential for planning of socio-economic activities. An effort has been done by the author in the present article to study and analyze the simulated synoptic climate parameters over Haryana from 1979 to 1993 by ECMWF (European Centre for Medium Range Weather Forecasts) through its Re-Analysis project, ERA-15.

ERA-15: ERA is the simply abbreviation of ECMWF Re-analyses data of 15 year climate 1979 to 1993. ECMWF use global spectral model to predict the weather and climate. It uses T106 resolution with 31 vertical hybrid levels. T106 means the entire globe 360 degree longitudes are denoted by 106 + 106 = 212 transverse nodes which implies the grid distance is roughly 200Kms . Reanalysis means generating data at any required point of interest, given the real observations in close or distant proximity of the point. The data generation follows the different steps. 1) Collecting the actual observed data both surface and upper air as on time and date from different locations and sources through mutual coordination of constituent organizations of different countries. 2) The Collected data is mapped (or) represented on to the required coordinate system of the region of interest. In this case the ECMWF follows a multilayer global model. The global model means it is global spectral model which is nothing but a computer model in which algorithms of six basic primitive equations of numerical weather prediction are represented in finite difference form forming a closure scheme. The data is represented on to a grid format in rectangular coordinate system or any other projection system based on the global model coordinate axes (i.e., spherical, cylindrical or parabolic etc as the case may be depending on the model formation with respect to the parameterization of physical variables). 3) The grid data is interpolated so that the interpolated data exactly suits the grid pattern and resolution of the global model. 4) Thus generated grid data is subjected to variational analysis to give variational grid data - means each variable of observation is subjected to regression so as to reduce the initial observational error. 5) The variational grid data is substituted in the global model equations and computed to predict the first future time step value of the each variable which is known as first guess. The magnitude of the time step varies on the algorithm choice during compilation and execution of the computer programme. 6) The first time step forecast value is recalculated subjected to variation in initial data of observation known as initialization. 7) Thus initialized data is put in the global model to compute and generate data at different model grid points by choosing different time step integration giving rise to the forecast values ranging from one second to few days to beyond years even ranging to climate averages. 8) Thus generated data is subjected to multiple initialization and forecast loop computation to get best predicted values with minimum error which known as data assimilation. Hence, a reanalysis is a comprehensive global, multi-decadal dataset generated by latest numerical data assimilation techniques through global climate models using all possible different past observations (in space and time). Typical research applications which could make use of re-analyses include general circulation diagnostics, atmospheric low frequency variability, the global hydrological and energy cycle, studies of predictability, coupled ocean-atmosphere modelling and observing system performance (Burridge 1996). Bengtsson and Shukla (1988) asserted that in weather forecasting system, operational analyses are affected by major changes in models, analysis technique, assimilation, and data usage. They also expressed the idea that such considerations provide valid reasons for performing a consistent re-analyses of atmospheric data. The first re-analyses project, ERA-15 was completed in 1995 generated data from December 1978 to February 1994 (Gibson 1997). The second extended reanalysis project, ERA-40 (1957-2002) is completed in 2002 (Uppala 2002). ECMWF is currently producing ERA-Interim, a new global reanalysis of the data-rich period since 1989. The ERA-Interim is expected to catch up with operations in late 2008.

Several attempts have been undertaken to create precipitation climatologies (e.g, Jaeger 1976; Legates 1990). These bear a high amount of uncertainty due to the sampling methodology. Model-based datasets of precipitation resulted as by-products of daily operational numerical weather forecasts. Precipitation in models is not analysed but gained from the atmospheric forecast model which is providing the first guess field. This implies that due to numerous changes both in model layout and assimilation no temporal consistency of such datasets can be expected (Tiedtke 1993; Arpe 1991, 1998). The variability in precipitation and cloud cover in the re-analysis data assumes significance in terms of its validity on different time scales. In the following simulated data of precipitation from ERA-15 and India Meteorological Department (IMD) precipitation observed data will be compared over Haryana.

2. STUDYAREA

Haryana plain is a fertile alluvial low land situated west of the Yamuna river and north of an arid desert. It also includes Delhi State between stony and broken slopes of Aravali mountains to the north and waterless desert tract to the south. This plain stretches like a corridor and merges in the east into the Ganga plain. The northeast part of the state is occupied by the Siwalik Hills. Two climatic types mostly humid subtropical summer and dry winter prevail over the region. The western disturbances reaching Rajasthan, Haryana, and Punjab slow down in June to October. So Haryana is warm in the summer and cool in the winter season. The monsoon will be active over Haryana during July, August and September. In May and June the weather over Haryana is associated with dust storms and thundershowers.

The present study area of Haryana state considers the geographical coordinates in various directions as follows: in north-east (Chandigarh: 30.43°N-76.47°E), in south- east (Faridabad: 28.24°N- 76.58°E), in south-west (Narnaul: 28.04°E-76.10°E), and in north-west (Sirsa: 29.32°N-75.04°E) covering geographical area about 4400 kilo-hectares. However, the data from meteorological centers like Ambala air force station and Hisar agro-met station are also considered.

3. METHODOLOGY AND DATA

ECMWF proposes to collect the feedback

from various countries regarding the performance of ERA-15 and ERA-40 models in particular with respect to precipitation patterns resulting in variations in global water cycles and the observational data update to propose required conventional measures to protect the global water cycles.

The Data for the present study has been taken from ERA-15 data generated by ECMWF. The ERA-15 assimilated surface weather data is extracted from the archive as per the locations (Lat. x Long.) specified above in the study area using Grads application software. Thus extracted data is subjected to interpolation so as to generate (1-Lat.x 1-Long. H" 120x120 Sq. Km) grid data comparable to model resolution used by ECMWF to generate ERA-15 data.

Statistical gazette of Haryana reveals the following meteorological and agricultural information. The annual rainfall over Haryana the century average is about 50 cm (Parthasarathi 1995). The annual rainfall corresponding to ERA-15 closing year 1993 is 46.96 cm. Haryana witnesses a lot of regional precipitation anomalies within a year. The precipitation varies from 1100 mm from north-east Haryana bordering H.P. to 300mm over south-west Haryana bordering Rajasthan. The meteorological records show that the intensity of precipitation on a rainy day in the monsoon season varies from 25mm/day to 21mm/day over NW-Haryana to SE-Haryana. Similarly, the intensity of precipitation on a rainy day in winter season varies from 12mm/day to 10mm/day over NW-Haryana to SE-Haryana.

The observed precipitation/rainfall data collected for all the district data of the Haryana spatially averaged to the above study area locations and subjected to the interpolation so as to generate the (1-Lat.x 1-Long. H" 120x120 Sq. Km) grid data for comparing with ERA-15 data. The space average of simulated and observed precipitation is compared.

The major component of ECMWF re-analysis project is to prepare the climatology of a fifteen-year period (1979-1993) ERA data. The 15-year climate of ECMWF re-analyses has been examined (Kallberg 1997) in the form of monthly field means, standard deviations and covariances. The prime purpose of the project has been quality monitoring of the analyses and short range forecasts and also low frequency variation in them, on time scales well above a month. Observation and model-generated biases and other weaknesses (due to parameterization) in assimilation system will influence the ERA climate. It is therefore very important to try to identify, and if possible, quantify aspects of the re-analyses that are due to the particular system used for their production rather than to the behaviour of the atmosphere.

The climate variables covered in this context are surface weather parameters – air temperature and dew point temperature (both at screen height), total cloud cover, total precipitation and evaporation. For these variables monthly averages have been taken into account. Using a surfer supported graphic package the inter-annual variations have been drawn separately for all the five variables. In addition

1. Correlation Coefficients between simulated daily total cloud cover (*x*) and precipitation (*Y*) over Haryana from the ERA data (1979-1993) for every day in all months, namely January to December have been computed.

- The correlation coefficients for linear fit {$y = mx+c$, *m*-slope of the line and c is y-intercept are constant for a given set of values.},
- For logarithmic fit {$y = a \ln x + b$, *a and b* are non-zero constants},
- For exponential fit {$y = A \exp(c\,x)$, A and c are constants}and
- For power fit {$y = B\,(X^{C}$, *B and c* are constants)} are calculated.

The every day cloud cover over Haryana during January to June and October to December is not consistent. There exists no seasonal cloud cover during most of these days over Haryana. When the variable *x becomes zero* in the above curve fitting formulae the arbitrary constants subjected vary drastically and some times the curve fitting formula can not be obtained. Since the cloud cover data is an assimilation data product of ERA, it is more required to take the correlation coefficients in all possible forms of curve fitting so that absence of cloud cover can be well taken care. Interestingly during monsoon months July, August and September over Haryana the Power fit and exponential fit correlations resulted in better form and in good agreement including the dates. The actual spells of rainfall occurrence are well coincided with ERA simulated data in terms of cloud cover. The correlation coefficients are tabulated month-wise in the tables 1-A to 1-L.

2. Performance of the ERA-15 model in terms of the total cloud cover, number of precipitation days, simulated and observed precipitation

during 1979-1993 has been evaluated for all the months January to December. Comparison of these variables are also shown in the table 2-A to 2-L.

4. RESULTS AND DISCUSSION

The global assimilated data of ERA-15 is represented in Mercator projection with respect to latitude and longitude along continental boundaries. The data of the surface and upper air weather parameters are represented in the form of contours/isolines. The required data namely temperature, dew point temperature, total cloud cover, total precipitation, and evaporation at the locations specified above in the study area is picked up using Grads software. The location specific data is interpolated to obtain the grid data (1Lat x 1Laong) comparable to the model generated data format. The grid data is space averaged. The analytic study of ERA data 1979-93, illuminates a lot of climatic information regarding the very short term cycles (cycle = periodic variation of the physical variable with time in terms of years) over Haryana among different surface weather variables. The variable-wise results have been listed in the ensuing text. In the following the simulated data of temperature, dew point temperature, total cloud cover, total precipitation, and evaporation and their temporal variation is listed and plotted as described in the sub-headings 4.1 to 4.5. In the section 4.6 correlation between simulated total cloud cover and total precipitation is discussed.

4.1 Temperature

Temporal variations of the temperature over Haryana simulated during 1979-93 are plotted in the figure 1. It is quite obvious to note that from the thermal pattern NW India would show the highest temperature in the pre-monsoon season and the lowest in winter season. Over Haryana from 1979 to 93, we get maximum temperatures in the months of May and June each year. It has been found that there is a 4-year cycle which governs the temperature pattern. The 4-year cycle shows an increasing trend in summer temperatures from 1980 to 1988, but the same 4-year cycle also shows a decreasing trend from 1988 to 1992. In addition to the 4-year cycle a 3-year cycle has also been found. This 3-year cycle is found to be more suitable. It has been obtained that from 1979 to 1988 the summer temperatures are increasing after that summer temperatures followed a decreasing trend from 1988 to 1993.

Year	*Month*	*Average tempera-ture (°C)*	*Year*	*Month*	*Average tempera-ture (°C)*
1979	May	36	1988	June	42
1980	May	33	1991	May	39
1982	May	37	1992	June	39
1984	May	41	1993	May	37
1985	May	40	1993	June	37
1988	May	43			

From the above two cycles, we can see that a significant 10-year cycle is inherently guiding the summer temperatures can be related to 11-year-sunspot cycle. If over a period of century the sunspot cycle study results are available more precise correlation between sunspot cycle and temperature variations can be obtained. The following figure.1 shows these results.

4.2 Dew Point Temperature

Temporal variations of the dew point temperature over Haryana simulated during 1979-93 are plotted in the figure.2. The maximum dew point temperatures from ERA simulated data over Haryana occur in the month of July/August. Here also we can find a 3-year cycle which shows the trend of increasing maximum dew point temperature in wet season from 1979 to 1988 then onwards decreasing trend from 1991 to 1993. The random variation from 1991 to 1993 may be due to the abnormal rainfall variation in 1993 which will cause moisture variation and thereby humidity mixing ratio. The figure 2 shows these results.

Year	*Month*	*Average dew point temperature (°C)*
1979	August	25
1982	August	26
1985	August	26.5
1988	August	26.5
1991	August	25
1993	August	26

4.3 Total Cloud Cover

Temporal variations of the total cloud cover over Haryana simulated during 1979-93 are plotted in the figure.3. From ERA-15 data over Haryana maximum cloud cover is assimilated in the monsoon season (July-September). The minimum cloud cover is simulated during post monsoon season October to December. A similar 3-year cycle of cloud cover also shows increasing trend from 1979 to 1988 and a decreasing trend from 1988 to 1993. These results are shown in the figure 3.

Year	*Month*	*Cloud Cover*	*Year*	*Month*	*Cloud Cover*
1979	Aug.	0.7	1988	Aug.	1.0
1982	Aug.	0.8	1991	Aug.	0.8
1985	Aug.	0.9	1993	July	0.7

4.4 Total Precipitation

Temporal variations of the total precipitation over Haryana simulated during 1979-93 are plotted in the figure.4.The total precipitation in the form of rainfall or fog over the study area is an outstanding feature and significant to the different agricultural practices. In wet season during July-September monsoon rainfall occurs over Haryana. From ERA-15 simulated data it can also be seen that during the same period the region receives maximum rainfall during ranges from 15cm to 50cm. Similarly precipitation secondary maximum occurs in winter during the months of December and January. In addition western disturbances and Himalayan snowfall events are also of great importance in winter precipitation. From figure.4 of total precipitation it is inherently clear that a 3-year cycle is present. An increasing trend from 1979 to 1988 and a decreasing trend from 1998 to 1993 in total precipitation found. Similar trends in winter precipitation are found during the same period. These results are shown in figure 4.

Year	*Month*	*Maximum Simulated Precipitation (Cm)*	*Year*	*Month*	*Maximum Simulated Precipitation (Cm)*
1979	July	25	1988	July	39
1982	Aug.	45	1991	Aug.	23
1985	July	28	1993	July	32

4.5 Evaporation

Temporal variations of the evaporation over Haryana simulated during 1979-93 are plotted in the figure.5. From ERA-15 data over Haryana the maximum evaporation is simulated in the monsoon months. It may be due to the maximum moisture and maximum possible conducive temperatures. No cycle is found. Maximum evaporation is simulated in the month of September and it is found in September 1989 the evaporation is the largest. Figure.5 presents the results.

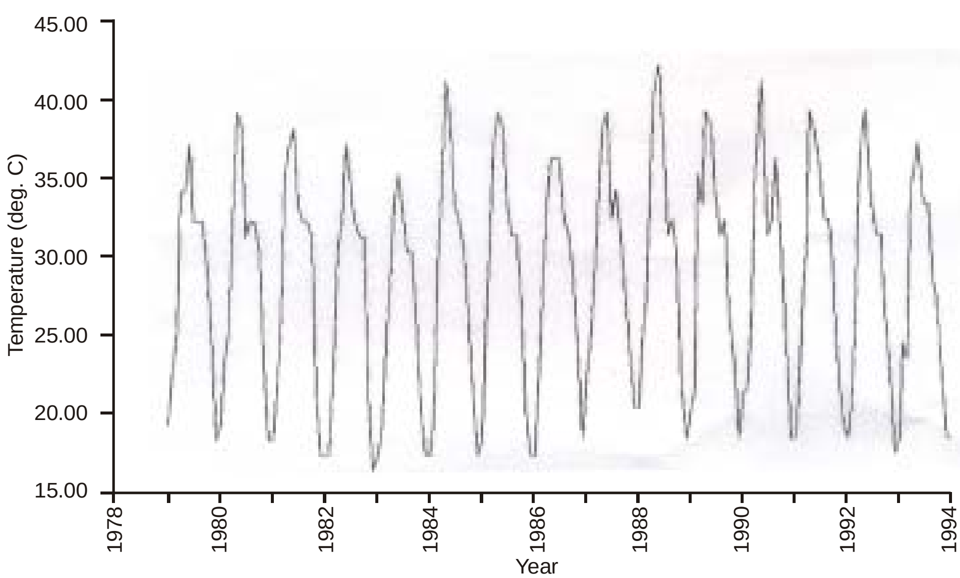

Fig. 1. Monthly Average Temperature simulated by ERA-15 mode over Haryana

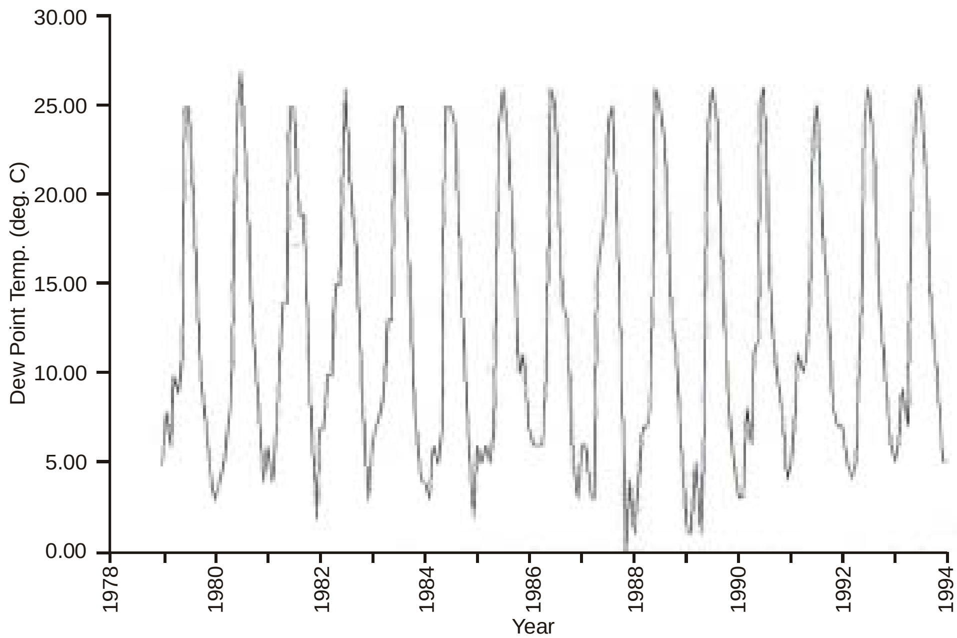

Fig. 2. Monthly Average Dew Point Temperature simulated by ERA-15 mode over Haryana

Figure in Corel Draw

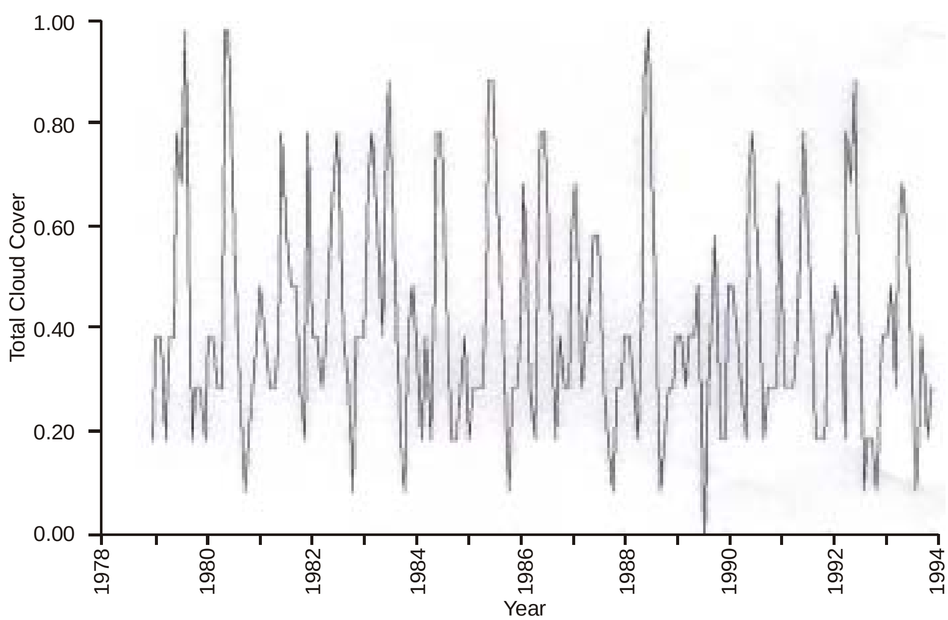

Fig. 3. Average Monthly Total Cloud Cover over Haryana simulated by ERA-15

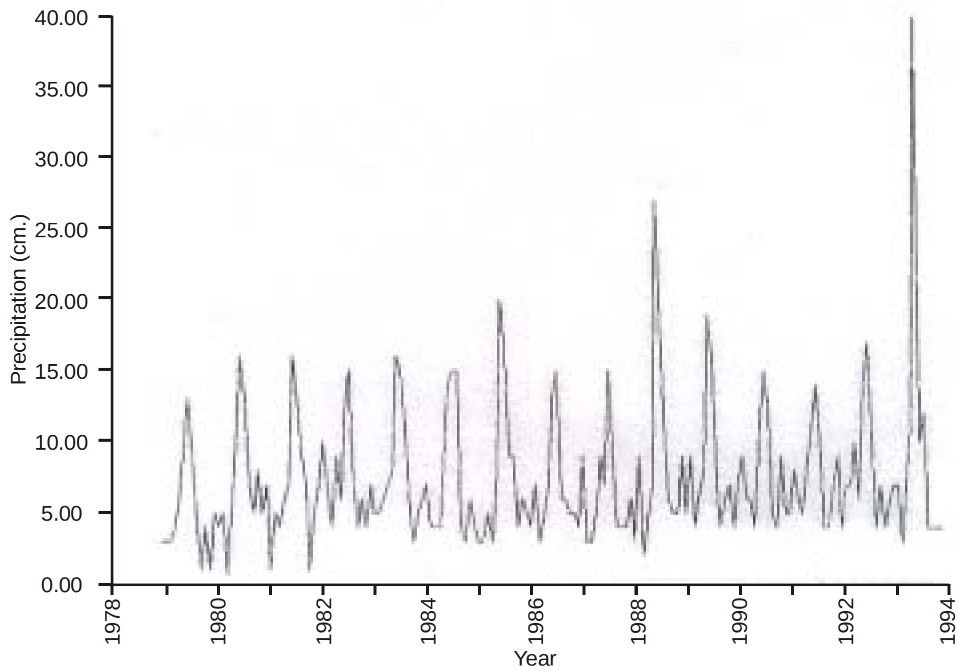

Fig. 4. Total Precipitation in cm simulated over Haryana by ERA-15

Figure in Corel Draw

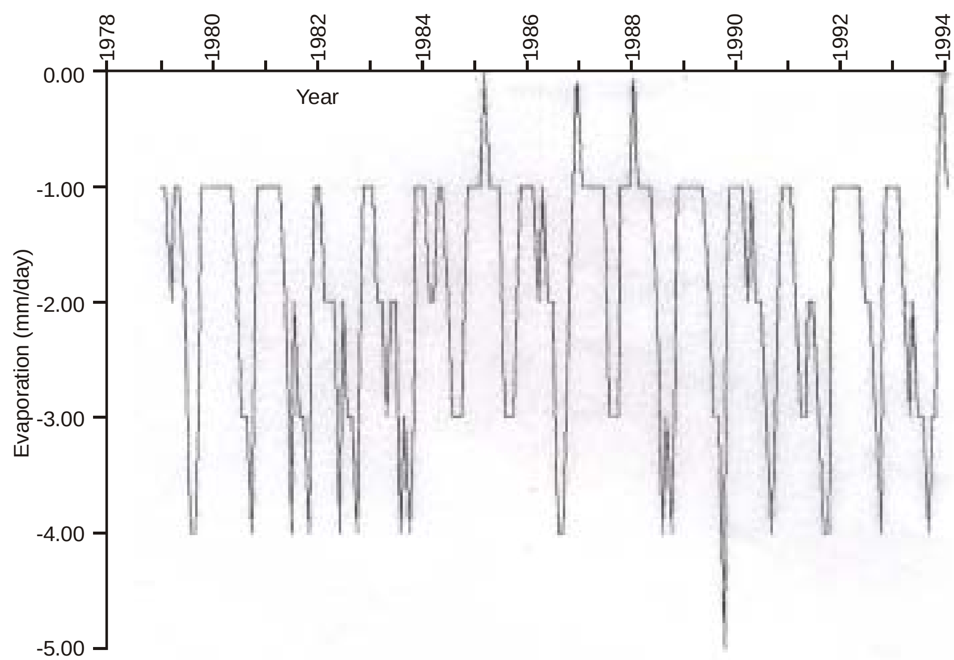

Fig.5. Evaporation (mm/day) simulated over Haryana by ERA-15

4.6 Correlation between Total Cloud Cover and Total Precipitation

The correlation coefficients are tabulated month wise in the Tables 1-A to Table 1-L. Simulated and observed precipitation during 1979-1993 has been evaluated for the 12- months and comparison of these variables are also shown in the table 2-A to Table 2-L.

Chevallier et al. (2003) in his report explains that the re-analysis programmes of numerical weather prediction (NWP) centres provide global, comprehensive description of atmosphere and earth surface over long periods of time. The high realism of their representation of key NWP parameters, like temperature and winds, implies some realism for less emblematic parameters such as cloud cover, but the degree of this realism need to be documented. Chevallier (2003) evaluated high cloud cover over open oceans in ERA-15 and ERA-40. The assessment is based on 23-climatology datasets of high cloud occurrence retrieved from infrared radiances measured by operational polar satellites. The

Table 1-A: Correlation Coefficients between simulated daily total cloud cover (x) and precipitation (Y) over Haryana from the ERA data (1979-1993)

January date	*Linear fit*	*Log. Fit*
1	$Y = 10.7023x + 0.8138$	$Y = 3.8341\ln x + 9.8042$
2	$Y = 6.8407x + 3.2355$	
3	$Y = -1.3306x + 4.3367$	
4	$Y = 5.8219x + 4.3150$	
5	$Y = 6.9884x + 2.6456$	
6	$Y = 17.5393x + 1.2356$	
7	$Y = 10.0256x + 4.1226$	
8	$Y = 3.3348x + 3.6439$	
9	$Y = 0.9632x + 4.6982$	
10	$Y = 5.2832x + 3.293$	
11	$Y = 5.2626x + 3.2933$	
12	$Y = 8.2117x + 0.5414$	$Y = 2.5075\ln x + 6.8569$
13	$Y = 8.8972x + 2.1303$	$Y = 3.3134\ln x + 10.2091$
14	$Y = 2.3248x + 6.3646$	$Y = 0.965\ln x + 8.6063$
15	$Y = 3.4091x + 3.4470$	$Y = 0.9017\ln x + 5.8908$
16	$Y = 0.9135x + 4.6102$	$Y = 0.1442\ln x + 5.1936$
17	$Y = 3.2901x + 6.0568$	$Y = -0.2766\ln x + 6.5491$
18	$Y = -0.0375x + 4.677$	
19	$Y = 3.9274x + 5.1098$	
20	$Y = 0.735x + 4.1887$	$Y = -0.5397\ln x + 3.0873$
21	$Y = 1.8545x + 3.7518$	$Y = 0.0986\ln x + 4.7739$
22	$Y = 3.8793x + 3.0948$	$Y = 0.8018\ln x + 5.4261$
23	$Y = 11.3275x + 1.4507$	$Y = 4.7886\ln x + 13.2692$
24	$Y = 13.3746x + 1.8567$	$Y = 0.7756\ln x + 6.3215$
25	$Y = 2.8689x + 4.0902$	$Y = 0.7756\ln x + 6.3215$
26	$Y = 9.1468x + 5.0689$	$Y = 2.8097\ln x + 12.5326$
27	$Y = 6.6498x + 3.2744$	$Y = 2.1903\ln x + 9.1805$
28	$Y = 13.355x + 1.8567$	$Y = 5.2654\ln x + 14.8716$
29	$Y = 25.3537x + 0.4937$	$Y = 9.1737\ln x + 24.5153$
30	$Y = 19.5097x + 0.4937$	$Y = 6.9897\ln x + 17.6811$
31	$Y = -0.4363x + 6.5137$	$Y = -0.4428\ln x + 5.7702$

Table 1-B: Correlation Coefficients between simulated daily total cloud cover (x) and precipitation (Y) over Haryana from the ERA data (1979-1993)

February date	*Linear fit*	*Log. Fit*
1	$Y = 1.5623x + 2.9688$	$Y = 1.1056 \ln x + 5.2275$
2	$Y = 1.5623x + 2.9688$	$Y = 1.1056 \ln x + 5.2275$
3	$Y = 5.043x + 2.3834$	
4	$Y = -2.6456x + 7.1129$	$Y = -1.0635 \ln x + 4.6613$
5	$Y = 6.61E–0.09x + 3.33$	$Y = 0.0382\ln x + 3.2675$
6	$Y = 0.2088x\ 4.2414$	
7	$Y = 8.614x + 1.2435$	$Y = 2.816\ln x + 8.4856$
8	$Y = -2.8150x + 3.5255$	$Y = -0.4918\ln x + 2.0493$
9	$Y = 1.8159x + 5.2914$	$Y = 1.2129\ln x + 7.0602$
10	$Y = 7.9451x + 1.1179$	$Y = 2.3449\ln x + 7.5349$
11	$Y = 11.6625x – 0.7427$	$Y = 2.7276\ln x + 9.7757$
12	$Y = 4.4869x + 1.9099$	$Y = 1.7918\ln x + 6.2689$
13	$Y = 8.4599x + 0.9957$	
14	$Y = 4.5732x + 3.3801$	$Y = 1.5105\ln x + 7.198$
15	$Y = 6.0379x + 1.1389$	$Y = 2.2641\ln x + 7.1862$
16	$Y = 7.3909x + 1.7364$	$Y = 1.9531\ln x + 7.2832$
17	$Y = 8.5539x + 1.8941$	$Y = 3.1111\ln x + 9.5751$
18	$Y = 14.4399x – 0.3648$	$Y = 4.2715\ln x + 11.023$
19	$Y = 11.6815x + 1.9037$	$Y = 3.5558\ln x + 11.4459$
20	$Y = 9.1056x + 1.2661$	$Y = 3.6111\ln x + 9.1776$
21	$Y = 8.3489x + 1.0494$	$Y = 1.9651\ln x + 6.8942$
22	$Y = -1.0x + 6.0667$	$Y = -0.576\ln x + 4.9599$
23	$Y = 5.902x + 1.9933$	
24	$Y = 10.2896x\ 0.0609$	$Y = 3.7818\ln x + 9.8293$
25	$Y = 14.2559x + 3.2962$	$Y = 4.5688\ln x + 15.3912$
26	$Y = 13.946x -1.9431$	$Y = 4.6283\ln x + 10.5673$
27	$Y = 13.1076x – 0.625$	
28	$Y = 12.1341x + 1.8911$	$Y = 4.2714\ln x + 12.9823$
29	$Y = 22.7273x -3.6364$	$Y = 7.7024\ln x + 16.1743$

Table 1-C: Correlation Coefficients between simulated daily total cloud cover (x) and precipitation (Y) over Haryana from the ERA data (1979-1993)

March-date	*Linear fit*	*Log. Fit*
1	$Y = 17.0886x + 0.5401$	$Y = 5.7659\ln x + 15.1504$
2	$Y = 10.3182x + 1.1434$	
3	$Y = 1.7819x + 4.0014$	$Y = 0.4358\ln x + 5.3163$
4	$Y = 20.4995x – 2.7845$	$Y = 6.9765\ln x + 5.3163$
5	$Y = 8.6496x + 2.3996$	$Y = 2.9861\ln x + 10.1886$
6	$Y = 13.404x – 0.0765$	$Y = 3.9844\ln x + 11.3374$
7	$Y = 3.6173x + 3.1999$	$Y = 1.5543\ln x + 6.1712$
8	$Y = 21.8106x -2.2455$	$Y = 7.2521\ln x + 16.6504$
9	$Y = 4.4993x + 1.8069$	$Y = 1.6293\ln x + 5.8146$
10	$Y = -1.6304x + 6.7609$	$Y = -0.0262\ln x + 5.9721$
11	$Y = 7.2595x + 2.5461$	$Y = 2.6486\ln x + 9.1419$
12	$Y = 110849x + 2.3428$	$Y = 3.6121\ln x + 11.5795$
13	$Y = 13.5184x + 1.0161$	$Y = 5.5983\ln x + 13.2781$
14	$Y = 9.4578x + 1.06398$	$Y = 3.2935\ln x + 9.2964$
15	$Y = -2.8017x + 4.9497$	$Y = -0.5224\ln x + 3.4042$
16	$Y = 0.7956x + 6.0894$	$Y = 1.0224\ln x + 7.9051$
17	$Y = 6.1788x + 2.0096$	
18	$Y = 10.3185x + 2.2429$	$Y = 3.6098\ln x + 11.3147$
19	$Y = 5.6777x + 2.6911$	$Y = 2.1905\ln x + 7.8913$
20	$Y = 8.6124x + 1.8421$	$Y = 3.2185\ln x + 9.5875$
21	$Y = 11.4823x – 0.0522$	$Y = 3.8168\ln x + 9.7759$
22	$Y = 12.6299x – 0.4972$	$Y = 4.3419\ln x + 10.6518$
23	$Y = 11.3673x + 1.3010$	$Y = 4.2693\ln x + 12.095$
24	$Y = 22.9758x – 1.2625$	$Y = 6.8544\ln x + 16.6656$
25	$Y = 8.0237x + 3.0541$	$Y = 3.2944\ln x + 10.446$
26	$Y = 5.0597x + 4.4027$	$Y = 1.4473\ln x + 8.4801$
27	$Y = 20.0195 – 1.4063$	$Y = 5.4063\ln x + 12.7484$
28	$Y = 2.994x + 3.2535$	$Y = 1.1291\ln x + 5.9512$
29	$Y = 4.6778x + 2.7547$	$Y = 1.6416\ln x + 6.8732$
30	$Y = 2.6716x + 3.514$	
31	$Y = -6.9186x + 5.0349$	$Y = -1.3519\ln x + 1.2438$

Table 1-D: Correlation Coefficients between simulated daily total cloud cover (x) and precipitation (Y) over Haryana from the ERA data (1979-1993)

April date	*Linear fit*	*Log. Fit*
1	$Y = -0.9285x + 4.2538$	$Y = -0.0955\ln x + 3.8401$
2	$Y = 6.4298x + 0.1613$	$Y = 2.4783\ln x + 5.8746$
3	$Y = 0.8351x + 3.8712$	$Y = 9.5656\ln x + 5.1113$
4	$Y = -1.9355x + 3.7098$	$Y = -0.3817\ln x + 2.4917$
5	$Y = 5.3249x + 3.9982$	
6	$Y = 9.903x - 0.3638$	$Y = 3.8105\ln x + 8.6049$
7	$Y = -2.7094x + 7.4713$	$Y = -0.9694\ln x + 5.1104$
8	$Y = 5.4311x + 3.2333$	
9	$Y = 5.7148x + 3.0664$	$Y = 2.5814\ln x + 8.6510$
10	$Y = 0.3478x + 3.9142$	
11	$Y = 4.2568x + 2.8293$	$Y = 2.3156\ln x + 7.6061$
12	$Y = 2.7199x + 2.2635$	$Y = 1.5414\ln x + 5.3275$
13	$Y = 12.1914x + 1.9444$	$Y = 3.8315\ln x + 11.7428$
14	$Y = 10.6742x + 2.4644$	
15	$Y = 20.0893x - 0.0268$	$Y = 5.1182\ln x + 13.9688$
16	$Y = 9.3891x + 3.3710$	$Y = 3.1834\ln x + 9.3745$
17	$Y = 12.2408x + 0.3139$	$Y = 3.3363\ln x + 9.3745$
18	$Y = 7.4972x + 2.0342$	$Y = 3.1140\ln x + 9.1801$
19	$Y = -1.5132x + 3.3732$	$Y = 0.0092\ln x + 3.0167$
20	$Y = -1.1335x + 4.2569$	$Y = -0.5913\ln x + 2.9658$
21	$Y = -2.5463x + 3.8657$	$Y = -0.8409\ln x + 1.7500$
22	$Y = -4.600x + 4.5600$	$Y = -1.1384\ln x + 1.5141$
23	$Y = 1.1859x + 3.9618$	$Y = 0.4132\ln x + 4.9695$
24	$Y = 11.2691x + 1.5864$	$Y = 2.2059\ln x + 8.0867$
25	$Y = -4.4872x + 4.6795$	$Y = -1.8318\ln x + 0.5882$
26	$Y = -7.3756x + 7.1527$	$Y = -2.5366\ln x + 1.1119$
27	$Y = 3.6642x + 2.5186$	
28	$Y = 7.0946x + 5.1081$	$Y = 2.1946\ln x + 10.3523$
29	$Y = 1.9737x + 4.7807$	
30	$Y = 3.6765x + 5.4902$	$Y = 0.5742\ln x + 7.5084$

ERA-15 and ERA-40 analyses and short range forecasts have been compared to high resolution infrared radiation sounder (HIRS) climatology. It is reported that nearly 40% of observed anomalies exists in ERA-15 from 1979 to 1994 with respect to seasonal and interannual variation of high clouds. ERA-40 improves these anomalies. Chevallier et al. (2003) noted that in ERA-15 and as well in ERA-40 there exists an imbalance between analyses and model physics. For validation of cloud cover analyses the use of geo-stationary data would be more appropriate (Kelly 2002).

So, ERA-15 data of cloud cover has anomalies thus resulting in simulated precipitation either excess or less than the actual observed precipitation at ground station.

Precipitation is highly variable both in reality and numerical models. Therefore in ERA-data it is compared precipitation sums that averaged over a certain region and time period inorder to detect the biases from parameterization of convection and large scale precipitation or from other errors in the analysis/forecasting scheme (Marten 1999). Closing down to our interest over Haryana (small scale region when compared to

Table 1-E: Correlation Coefficients between simulated daily total cloud cover (x) and precipi-tation (Y) over Haryana from the ERA data (1979-1993)

May date	*Linear fit*	*Log. Fit*
1	$Y = 4.7244x + 1.2992$	$Y = 1.7210\ln x + 5.2345$
2	$Y = 25x + 1.6667$	$Y = 2.1584\ln x + 10.3422$
3	$Y = 5.3354x + 5.5549$	$Y = 6.8473\ln x + 18.1131$
4	$Y = 0.375x + 6.825$	$Y = -0.4562\ln x + 6.5277$
5	$Y = -2.9494x + 6.6292$	$Y = 0.7917\ln x + 7.335$
6	$Y = 0.2544x + 3.5938$	$Y = 1.163\ln x + 5.5087$
7	$Y = 4.8899x + 4.5151$	$Y = 2.4626\ln x + 9.8930$
8	$Y = 5.4348x + 2.8261$	$Y = 2.0789\ln x + 7.4267$
9	$Y = 0.0759x + 6.2994$	$Y = 1.8455\ln x + 8.1503$
10	$Y = 5.1456x + 2.3438$	$Y = 2.0393\ln x + 6.8509$
11	$Y = 9.194x + 5.5139$	$Y = 3.6758\ln x + 11.3611$
12	$Y = 25.8612x + 0.7698$	$Y = 7.5506\ln x + 18.9382$
13	$Y = 16.9453x - 0.5243$	$Y = 5.3805\ln x + 12.5565$
14	$Y = 16.4x + 0.84$	$Y = 4.9294\ln x + 13.5021$
15	$Y = 11.98x + 2.5783$	$Y = 4.3717\ln x + 12.6886$
16	$Y = -4.1513x + 6.3284$	$Y = -0.9199\ln x + 3.6214$
17	$Y = 13.8691x + 5.5654$	$Y = -0.1356\ln x + 5.8024$
18	$Y = 7.8244x + 3.1429$	$Y = 1.9951\ln x + 8.3285$
19	$Y = 1.7609x + 6.2487$	$Y = 0.3810\ln x + 7.4293$
20	$Y = -4.1284x + 9.7889$	$Y = -1.3499\ln x + 6.4100$
21	$Y = -0.4629x + 7.1759$	$Y = -0.2910\ln x + 6.6434$
22	$Y = 13.0297x + 2.7154$	$Y = 4.5786\ln x + 13.0792$
23	$Y = 1.00x + 7.3$	$Y = 1.03112\ln x + 9.0801$
24	$Y = 20.659x + 1.1716$	$Y = 5.9513\ln x + 16.1052$
25	$Y = 11.5214x + 1.0320$	$Y = 3.8746\ln x + 9.8592$
26	$Y = -0.5405x + 6.8648$	$Y = 0.1393\ln x + 6.8496$
27	$Y = 17.4927x - 0.4815$	$Y = 4.0978\ln x + 10.5617$
28	$Y = 4.5164x + 3.101$	$Y = 0.6519\ln x + 5.8481$
29	$Y = 7.5994x + 3.3752$	$Y = 2.4621\ln x + 9.1760$
30	$Y = 9.9282x - 0.5742$	$Y = 2.9047\ln x + 6.7389$
31	$Y = 1.9050x + 3.7396$	$Y = 0.6339\ln x + 5.2678$

Table 1-F: Correlation Coefficients between simulated daily total cloud cover (x) and precipi-tation (Y) over Haryana from the ERA data (1979-1993)

June date	*Linear fit*	*Log. Fit*
1	$Y = -5.2215x + 7.2627$	
2	$Y = 2.1034x + 4.7711$	$Y = 2.0167\ln x + 8.4383$
3	$Y = 1.9084x + 4.8397$	$Y = 0.5928\ln x + 6.2748$
4	$Y = -7.219E\text{-}08x + 3.33$	$Y = -0.6601\ln x + 2.3827$
5	$Y = 10.4962x + 1.6412$	$Y = 2.9395\ln x + 8.9182$
6	$Y = 8.1169x + 4.1688$	$Y = 1.2478\ln x + 8.3034$
7	$Y = 13.0097x + 1.6602$	$Y = 3.8369\ln x + 11.7037$
8	$Y = 6.1688x + 2.8247$	$Y = 2.1789\ln x + 7.9703$
9	$Y = 2.5210x + 5.1597$	$Y = 1.6014\ln x + 8.1726$
10	$Y = 1.5246x + 5.8231$	$Y = 1.4118\ln x + 7.9629$
11	$Y = 25.3049x + 0.5641$	$Y = 8.6247\ln x + 21.1859$
12	$Y = 6.7514x + 4.7409$	$Y = 2.1769\ln x + 10.0452$
13	$Y = 0.7162x + 8.7517$	$Y = -0.11073\ln x + 8.8448$
14	$Y = 7.0811x + 3.6988$	$Y = 2.4778\ln x + 9.5199$
15	$Y = 6.25x + 4.625$	$Y = 2.3831\ln x + 9.9760$
16	$Y = -1.5047x + 4.4619$	$Y = -0.4939\ln x + 3.2891$
17	$Y = 8.8918x + 4.1323$	$Y = 4.141\ln x + 12.5688$
18	$Y = 10.8696x + 2.2609$	$Y = 3.0999\ln x + 10.3745$
19	$Y = -3.2918x + 12.8915$	$Y = -2.09816\ln x + 9.4264$
20	$Y = 9.2379x + 2.1709$	$Y = 4.2024\ln x + 10.0661$
21	$Y = 7.4297x + 3.1957$	$Y = 2.6012\ln x + 9.9436$
22	$Y = -1.2136x + 8.8430$	$Y = 0.5068\ln x + 8.8769$
23	$Y = 16.0272x - 0.1889$	$Y = 3.6182\ln x + 11.6697$
24	$Y = 20.8058x + 3.0713$	$Y = 6.7803\ln x + 19.7188$
25	$Y = 6.2298x + 6.8447$	$Y = 1.9096\ln x + 11.8506$
26	$Y = 2.1615x + 9.1817$	$Y = 1.4548\ln x + 11.3973$
27	$Y = 19.3396x - 0.9371$	$Y = 6.9577\ln x + 15.4257$
28	$Y = 9.8039x + 3.8039$	$Y = 5.4710\ln x + 13.3431$
29	$Y = 21.6937x - 2.4942$	$Y = 7.7679\ln x + 16.001$
30	$Y = 18.143x + 0.5123$	$Y = 7.3757\ln x + 17.1906$

Table 1-G: Correlation Coefficients between simulated daily total cloud cover (*x*) and precipitation (*Y*) over Haryana from the ERA data (1979-1993)

July date	*Linear fit*	*Log. Fit*	*Exponential fit*	*Power fit*
1	Y=*11.2984*x+*2.1664*	*Y=5.1431*lnx*+12.4756*		
2	*Y*=14.0625*x*+2.1563	*Y*=*3*.5007lnx +13.8714		
3	*Y*=21.6495*x* +1.4329	*Y* = 8.3492lnx +17.696	*Y*=3.411*exp(*1.6587*x)*	*Y*=14.9948*(x***0.6722*)*
4	*Y*= 3.5348*x* +9.2360	*Y* =0.4823ln*x*+11.6922		
5	*Y*=13.6213*x*+3.7375	*Y*=3.6642ln*x* +15.0679	*Y*=6.115*exp*(0.9105*x)*	*Y*=12.9274*(x***0.2305*)*
6	*Y*=30.6229*x* –6.9735	*Y*=11.1631ln*x*+20.1454		
7	*Y*=12.50*x* +3.9167	*Y*=5.7591ln*x*+15.2674		
8	*Y*=29.0142*x* -6.7503	*Y*= 5.4212ln*x* +16.8725		
9	*Y*=22.2841*x* –0.2293	*Y*= 7.2996ln*x* +19.003		
10	*Y*=18.3333*x* +1.50	*Y* =5.4213ln*x* +16.8725		
11	*Y*=39.865*x* –17.892	*Y*= 18.2995ln*x* +19.252		
12	*Y*=27.3256*x* –5.4651	*Y*=10.9471ln*x*+19.7674		
13	*Y*=33.2298*x* –2.7019	*Y*=12.0344ln*x*+26.8087	*Y*=6.0625*exp*(1.4025*x)*	*Y*=21.1915*(x***0.5218*)*
14	*Y*=26.7857*x* –3.2143	*Y*= 8.7085ln*x* +20.0131		
15	*Y*=20.195*x* +3.3890	*Y* = 7.286ln*x* +21.882	*Y*=6.1964*exp*(1.2395*x)*	*Y*=19.5835*(x***0.4794*)*
16	*Y*= 12.9916*x*+5.927	*Y* = 4.7003ln*x*+18.0462	*Y*=7.6193*exp*(0.7624*x)*	*Y*=15.4862*(x***0.2692*)*
17	*Y*=5.943*x* +10.4273	*Y* =1.2489ln*x* +15.3255		
18	*Y*= 6.5813*x* +8.4541	*Y*=5.7432ln*x* +15.6387		
19	*Y*= 17.0213*x* –0.617	*Y*=4.8232ln*x* +14.5799		
20	*Y*=17.3567*x*+0.8227	*Y*=6.5795ln*x* +16.8035		
21	*Y*= 26.699*x* –3.4952	*Y*=9.2477ln*x* +22.0669		
22	*Y*= 24.496*x* +0.2198	*Y*=11.0386ln*x*+23.8967		
23	*Y*= 24.3674*x* –1.169	*Y* =7.5951ln*x* +21.1757		
24	*Y*=12.8365*x*+8.7488	*Y*=6.4050ln*x* +21.354		
25	*Y*=26.4218*x* –4.3325	*Y*=8.8236ln*x* +19.9471	*Y*=3.2349*exp*(1.7986*x)*	*Y*=17.1513*(x***0.6525*)*
26	*Y*= -2.5381*x*+20.212	*Y*=-3.0287ln*x*+16.8084		
27	*Y*=22.4916*x*+3.0884	*Y*=7.1797ln*x* +22.9335	*Y*=6.4305*exp*(1.2111*x)*	*Y*=18.8994*(x***0.3988*)*
28	*Y*=-0.4662*x*+17.874	*Y*=2.7962ln*x* +18.1329	*Y*=14.82exp*(*-0.0216*x)*	*Y*=15.0804*(x***0.1475*)*
29	*Y*= 10.3316*x* +5.608	*Y* =3.1293ln*x* +14.7425	*Y*=8.123*exp*(0.5382*x)*	*Y*=13.099*(x***0.1615*)*
30	*Y*= 9.0416*x* +6.2206	*Y* =4.1042ln*x* +14.5868	*Y*=8.06*exp*(0.5435*x)*	*Y*=13.3431*(x***0.2506*)*
31	*Y*=34.2652*x* –12.955	*Y*=24.2728ln*x*+20.4094		

Table 1-H: Correlation Coefficients between simulated daily total cloud cover (*x*) and precipitation (*Y*) over Haryana from the ERA data (1979-1993)

August date	*Linear fit*	*Log. Fit*	*Exponential fit*	*Power fit*
1	Y=*15.5738*x+*3.005*	*Y=24.0413lnx+18.4058*		
2	*Y*=33.6207*x* -14.569	*Y*=11.3359ln*x*+18.4239	*Y*=0.2038*exp*(0.6124*x)*	*Y*=15.074*(x***0.4679*)*
3	*Y*=13.0893*x*+2.3697	*Y* =9.2591ln*x* +15.1969		
4	*Y*=35.9673*x*–13.733	*Y* = 26.374ln*x* +21.745		
5	*Y*=27.7695*x*–1.7715	*Y* =11.0977ln*x* +23.994	*Y*=4.8267exp*(*1.4275*x)*	*Y*=18.503*(x***0.6164*)*
6	*Y*= 18.75*x* +0.4167	*Y*=2.3859ln*x* +18.6063	*Y*=4.3969*exp*(1.4059*x)*	*Y*=17.12*(x***0.9146*)*
7	*Y*=26.4706*x*–5.0588	*Y*=18.8859ln*x*+20.9199	*Y*=4.4706*exp(*1.437*x)*	*Y*=18.3147*(x***1.0248*)*
8	*Y*=37.2596*x*–12.043	*Y*=23.9306ln*x*+24.6812	*Y*=1.7595*exp(*2.642*x)*	*Y*=23.9839*(x***1.9091*)*
9	*Y*=20.7143*x*–3.2857	*Y*=17.8738ln*x*+17.4155	*Y*=4.6486*exp(*1.2219*x)*	*Y*=15.7564*(x***1.0514*)*
10	*Y*= 3.7015*x* +7.3968	*Y* =2.3587ln*x* +10.9561	*Y*=8.1856*exp(*0.2524*x)*	*Y*=10.4034*(x***0.1498*)*
11	*Y*=12.007*x* +4.2882	*Y*= 8.0569ln*x* +16.0357	*Y*=6.7306*exp*(0.8323*x)*	*Y*=15.1947*(x***0.5585*)*
12	*Y*=17.5565*x* +2.423	*Y*=11.524ln*x* +19.5332		
13	*Y*=20.3704*x*–0.2963	*Y*=10.5599ln*x*+18.7773		
14	*Y*= 8.0306*x* +5.4685	*Y* =5.3134ln*x* +13.3239	*Y*=7.6289*exp*(0.4796*x)*	*Y*=12.196*(x***0.3173*)*
15	*Y*=11.6279*x*+4.1861	*Y*= 5.5091ln*x* +15.0679	*Y*=6.9105*exp*(0.7391*x)*	*Y*=13.8005*(x***0.3502*)*
16	*Y*=17.6849*x*+2.8725	*Y*=8.0217ln*x* +19.5807	*Y*=7.292*exp*(0.7836*x)*	*Y*=15.2883*(x***0.3554*)*
17	*Y*=2.8796*x*+11.9721	*Y*=1.7210ln*x* +14.7692	*Y*=12.571*exp*(0.0123*x)*	*Y*=12.743*(x***0.0137*)*
18	*Y*=24.361*x* –3.1182			
19	*Y*=24.1936*x*-5.9677	*Y*=14.4442ln*x*+17.4247	*Y*=3.3249*exp*(1.5634*x)*	*Y*=15.0175*(x***0.9106*)*
20	*Y*=11.2269*x*+3.4607	*Y*=5.466ln*x*+14.2961		
21	*Y*=14.823*x* +5.7965	*Y*=7.3759ln*x*+19.4295	*Y*=7.413*exp*(0.923*x)*	*Y*=17.3628*(x***0.465*)*
22	*Y*=6.8087*x*+8.5821	*Y*=4.7887ln*x*+15.1718	*Y*=9.7817*exp*(0.3133*x)*	*Y*=13.2479*(x***0.2208*)*
23	*Y*=11.7424*x*+0.5303			
24	*Y*=33.482*x* -14.4494	*Y*=27.2481ln*x*+18.7514		
25	*Y*=12.0504*x*+2.8417	*Y*=6.2815ln*x*+13.8455	*Y*=5.0374*exp*(0.9734*x)*	*Y*=12.3666*(x***0.5113*)*
26	*Y*=25.1944*x*–6.8118	*Y*=14.1188ln*x*+17.0447		
27	*Y*=37.703*x*–12.4797	*Y*=18.3853ln*x*+22.3434		
28	*Y*=24.2857*x*-7.6667	*Y*=12.1498ln*x*+14.4625		
29	*Y*=*13x* -1	*Y*=6.3773ln*x* +10.7398		
30	*Y*=12.3693*x*+2.7434	*Y*=5.1229ln*x*+14.1412		
31	*Y*=9.5472*x* +2.3655	*Y* = 3.306ln*x* +10.4894		

Table 1-I: Correlation Coefficients between simulated daily total cloud cover (x) and precipitation (Y) over Haryana from the ERA data (1979-1993)

September date	*Linear fit*	*Log. Fit*	*Exponential fit*	*Power fit*
1	$Y=19.206x+0.1695$		$Y=3.518\exp(1.577x)$	
2	$Y=9.4595x+3.0517$	$Y=5.785\ln x+12.078$	$Y=3.415\exp(1.0303x)$	$Y=8.7281(x{*}{*}0.522)$
3	$Y=4.9716x+5.1847$	$Y=1.102\ln x+9.0164$		
4	$Y=16.0034x-0.7623$	$Y=5.468\ln x+13.136$		
5	$Y=4.8007x+6.0236$	$Y=1.8876\ln x+9.759$		
6	$Y=16.4402x-1.5172$	$Y=8.3667\ln x+13.44$		
7	$Y=5.0336x+6.9128$	$Y=2.263\ln x+11.194$		
8	$Y=10.8119x+3.774$	$Y=4.9144\ln x+13.21$		
9	$Y=17.3885x+1.581$	$Y=5.764\ln x+16.33$		
10	$Y=22.337x-2.1397$	$Y=9.336\ln x+17.726$		
11	$Y=-0.508x+6.954$	$Y=-0.3873\ln x+6.37$		
12	$Y=25.814x-1.0465$	$Y=7.588\ln x+18.871$		
13	$Y=11.857x+2.1381$			
14	$Y=13.75x+1.432$	$Y=5.7667\ln x+13.48$		
15	$Y=4.0837x+6.708$	$Y=1.0393\ln x+9.696$		
16	$Y=10.1868x+5.32$	$Y=2.7204\ln x+12.54$		
17	$Y=0.7042x+6.972$	$Y=0.5475\ln x+7.79$		
18	$Y=11.0054x+2.491$	$Y=4.234\ln x+11.494$		
19	$Y=6.5217x+2.3913$	$Y=1.7874\ln x+7.088$		
20	$Y=12.476x+1.1759$	$Y=3.3919\ln x+9.859$		
21	$Y=4.8137x+8.568$			
22	$Y=3.064x+7.605$	$Y=1.2325\ln x+10.37$		
23	$Y=13.448x+1.0323$	$Y=3.3981\ln x+10.64$		
24	$Y=16.1454x+2.702$	$Y=5.338\ln x+16.26$		
25	$Y=0.065x+4.967$			
26	$Y=3.2572x+6.0663$			
27	$Y=3.0488x+4.085$	$Y=0.6449\ln x+5.969$		
28	$Y=3.9773x+4.394$	$Y=0.6023\ln x+5.969$		
29	$Y=-8.886x+7.821$	$Y=-2.847\ln x+0.901$		
30	$Y=-0.5675x+8.1778$	$Y=-0.3199\ln x+7.51$		

Table 1-J: Correlation Coefficients between simulated daily total cloud cover (x) and precipi-tation (Y) over Haryana from the ERA data (1979-1993)

October date	*Linear fit*	*Log. Fit*
1	$Y = -4.2857x + 5.7142$	$Y = -1.0498\ln x + 2.9178$
2	$Y = -6.25x + 3.125$	$Y = -1.5533\ln x - 1.0767$
3	$Y = 10.8491x + 2.8585$	$Y = 3.1583\ln x + 11.006$
4	$Y = -0.6356x + 3.0932$	$Y = 7.0584E\text{-}0.15\ln x + 3$
5	$Y = 13.0814x + 0.9786$	$Y = 3.7338\ln x + 10.4828$
6	$Y = 12.5x + 3.1667$	$Y = 2.6646\ln x + 10.5751$
7	$Y = 1.5306x + 6.5918$	$Y = 0.4757\ln x + 7.7623$
8	$Y = 9.214x + 4.4815$	$Y = 2.3196\ln x + 10.8322$
9	$Y = 40.1863x - 5.7159$	$Y = 10.2486\ln x + 21.9422$
10	$Y = 7.9182x + 2.0107$	$Y = 2.8944\ln x + 8.6356$
11	$Y = 7.2412x + 3.3978$	$Y = 2.0604\ln x + 8.7799$
12	$Y = 15.1322x + 3.79216$	$Y = 4.3889\ln x + 15.1862$
13	$Y = 16.5709x + 0.3639$	$Y = 4.8366\ln x + 12.6913$
14	$Y = 5.2521x + 2.9160$	$Y = 1.9724\ln x + 7.3841$
15	$Y = 0.7732x + 3.8144$	$Y = 0.3847\ln x + 4.6866$
16	$Y = 2.6457x + 2.4003$	$Y = 0.9042\ln x + 4.6896$
17	$Y = 5.4878x + 1.0116$	$Y = 1.4577\ln x + 4.868$
18	$Y = 2.1966x + 1.5899$	$Y = 0.1726\ln x + 2.3402$
19	$Y = 4.1899x + 2.3278$	$Y = 1.3119\ln x + 5.6028$
20	$Y = 1.572x + 1.998$	$Y = 0.8344\ln x + 3.8987$
21	$Y = 10.1351x + 3.7162$	$Y = 1.1544\ln x + 7.4668$
22	$Y = -20.8333x + 6.25$	$Y = -3.7927\ln x - 4.6626$
23	$Y = 0.5947x + 4.1589$	$Y = -0.3225\ln x + 3.7817$
24	$Y = 1.1646x + 4.7981$	$Y = 0.61\ln x + 6.2306$
25	$Y = -17.5676x + 6.8919$	$Y = -3.4752\ln x - 2.7596$
26	$Y = 0.4854x + 3.5599$	$Y = -0.4529\ln x + 2.8224$
27	$Y = -4.9689x + 4.8261$	$Y = -1.6425\ln x + 0.6379$
28	$Y = 2.1058x + 3.6069$	$Y = 0.6893\ln x + 5.3764$
29	$Y = -6.25x + 4.5$	$Y = -1.3641\ln x + 0.8147$
30	$Y = -5.5825x + 5.4126$	$Y = -1.5407\ln x + 1.3552$
31	$Y = 3.3783x + 4.3919$	$Y = 2.2233\ln x + 9.297$

Table 1-K: Correlation Coefficients between simulated daily total cloud cover (x) and precipi-tation (Y) over Haryana from the ERA data (1979-1993)

November date	*Linear fit*	*Log. Fit*
1	$Y = 4.5455x + 2.7273$	$Y = 0.2578\ln x + 4.5533$
2	$Y = -9.3264x + 4.4301$	$Y = -2.6599\ln x - 2.4292$
3	$Y = -6.5934x + 7.3626$	$Y = -2.0497\ln x + 2.0599$
4	$Y = 3.7367x + 6.3523$	$Y = 1.4192\ln x + 9.9189$
5	$Y = 3.7367x + 6.3523$	$Y = 1.4192\ln x + 9.9189$
6	$Y = 4.5455x + 2.9091$	$Y = 1.2937\ln x + 6.2518$
7	$Y = -11.2069x + 5.5345$	$Y = -2.4193\ln x - 1.0665$
8	$Y = 4.5455x + 2.4546$	$Y = 1.2628\ln x + 5.8608$
9	$Y = 0.9615x + 3.8077$	$Y = 0.21011nx + 4.4013$
10	$Y = -3.5714x + 2.8571$	$Y = -1.2023\ln x - 0.2683$
11	$Y = 2.9661x + 2.5848$	$Y = 0.4587\ln x + 3.9808$
12	$Y = 1.2311x + 6.7046$	$Y = 7.3887\ln x + 8.3445$
13	$Y = 4.5455x + 2.1212$	$Y = 0.4853\ln x + 3.7262$
14	$Y = 4.8867x + 0.8347$	$Y = 1.6033\ln x + 5.0129$
15	$Y = 7.0802x + 2.8258$	$Y = 2.3413\ln x + 9.0351$
16	$Y = 6.3107x + 3.4466$	$Y = 1.5929\ln x + 7.7861$
17	$Y = -3.2154x + 4.2337$	$Y = -1.1012\ln x + 1.4545$
18	$Y = 1.2595x + 3.0479$	$Y = -0.0578\ln x + 3.2328$
19	$Y = -1.7341x + 4.1522$	$Y = -0.6927\ln x + 2.448$
20	$Y = 3.4091x\ 6+1.0227$	$Y = 1.1482\ln x + 3.9729$
21	$Y = 3.7129x + 3.9356$	$Y = 1.3348\ln x + 7.1891$
22	$Y = 3.9195x + 4.6006$	$Y = 0.9399\ln x + 7.3025$
23	$Y = 10.5292x + 3.0346$	$Y = 3.4462\ln x + 11.8819$
24	$Y = 13.2166x + 0.897$	$Y = 5.1794\ln x + 13.6489$
25	$Y = 2.1466x + 2.8897$	$Y = 0.6007\ln x + 4.5187$
26	$Y = 1.4151x + 4.6226$	$Y = 0.5824\ln x + 6.0476$
27	$Y = -1.4505x + 4.2662$	$Y = -0.3933\ln x + 3.0618$
28	$Y = 12.0183x + 0.4361$	$Y = 3.5929\ln x + 9.9407$
29	$Y = 7.3409x + 4.3943$	$Y = 2.6349\ln x + 11.0142$
30	$Y = 30.3725x + 2.0439$	

Table 1-L: Correlation Coefficients between simulated daily total cloud cover (x) and precipi-tation (Y) over Haryana from the ERA data (1979-1993)

December date	*Linear fit*	*Log. Fit*
1	$Y = -1.5625x + 2.1875$	$Y = -0.7102\ln x + 3.8317$
2	$Y = -1.4729x + 5.4615$	$Y = 0.1883\ln x + 2.4126$
3	$Y = 1.6667x + 1.7333$	
4	$Y = -5.2239x + 3.4328$	
5	$Y = -6.4607x + 5.2809$	
6	$Y = -1.2976x + 5.7572$	$Y = -0.3523\ln x + 7.4642$
7	$Y = -1.5625x + 2.9688$	
8	$Y = 4.0323x + 2.5$	$Y = 0.6368\ln x + 4.5669$
9	$Y = 8.0271x + 3.7814$	$Y = 2.6291\ln x + 10.4768$
10	$Y = 1.0000x + 2.1333$	
11	$Y = 3.1042x + 2.0067$	$Y = 1.1765\ln x + 4.8862$
12	$Y = 5.4416x + 2.047$	
13	$Y = 12.834x + 1.6365$	
14	$Y = 0.9542x + 4.1107$	$Y = 0.4576\ln x + 5.1583$
15	$Y = 8.6867x + 5.6257$	$Y = 3.8127\ln x + 14.5946$
16	$Y = 2.9204x + 3.4596$	
17	$Y = -1.5564x + 7.2374$	$Y = -0.3327\ln x + 6.1921$
18	$Y = 6.1897x + 5.6002$	$Y = 2.2999\ln x + 11.2641$
19	$Y = 0.0601x + 4.6835$	$Y = -0.2396\ln x + 4.2392$
20	$Y = 8.7332x + 0.9885$	$Y = 2.7125\ln x + 8.1442$
21	$Y = 15.6075x + 1.8610$	
22	$Y = 9.9788x + 1.4756$	$Y = 3.9294\ln x + 10.6058$
23	$Y = 20.4921x + 1.8961$	
24	$Y = 12.5x + 0.25$	$Y = 4.7874\ln x + 12.1849$
25	$Y = 4.2225x + 5.6873$	$Y = 2.1998\ln x + 10.1489$
26	$Y = 16.334x + 1.1064$	$Y = 5.7421\ln x + 15.9408$
27	$Y = 7.9496x + 1.6612$	
28	$Y = 8.285x + 4.4632$	$Y = 3.2315\ln x + 12.5005$
29	$Y = 31.0279x - 0.4676$	
30	$Y = 13.1868x + 0.04396$	$Y = 4.8401\ln x + 12.4305$
31	$Y = 14.1173x + 1.0903$	$Y = 4.9611\ln x + 13.2727$

global model), cloud cover and precipitation is not a target in ERA-15 as per Chevallier et al. (2003). But ECMWF global climate model is wet biased in its humidity analyses. Marten's (1999) study aimed at evaluation of precipitation estimates by ECMWF reanalysis. A comparison of different analysis schemes can help to identify sensitive areas.

So ERA-15 data of simulated precipitation at the selected study area locations of Haryana is compared and correlated to cloud cover.

Over Haryana, the ERA-15 model has well simulated the monsoon season wherein the precipitation period coincides with the actual observations during July and August months as shown from the power fit and exponential fit. Interestingly during monsoon months July, August and September over Haryana the Power fit and exponential fit correlations resulted in better form so that the actual spells of rainfall occurrence is well coincided with ERA simulated data in terms of cloud cover. The monsoon performance in fact is very good over Haryana during July and August as it can be seen from the India Meteorological Department (IMD) observations and records for the long years from 1870 to 1994.

IMD Observations reveal that the figures of magnitude of precipitation over Haryana are given as follows, during July for the years 1980 (Maximum) and 1987(Minimum); and during August for the years 1982 (Maximum) and 1993 (Minimum). The ERA-15 simulated results also show good coincidence of these extreme figures except in 1982 August. Much of the monsoon rainfall would occur due to the westward movement of monsoon depressions in association with intra tropical convergence zone (ITCZ) events. Chevallier et al (2003) reported in his study that ERA-ITCZ is static. So ERA-Interim is under way to improve these anomalies.

Table 2-A: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	January	³ 0.8	4 days	36	29.7	6.3	Little excess
1980	January	³0.9	5 days	13	11.2	1.8	Equal
1981	January	>0.9	2 days	30	27.4	2.6	Equal
1982	January	>0.9	6 days	39	17.7	21.3	Excess
1983	January	>0.9	4 days	60	49.6	10.4	Excess
1984	January	³0.9	6 days	15	1.4	13.6	Excess
1985	January	>0.9	2 days	2	2.0	0	Equal
1986	January	0.7	6 days	6	6.0	0	Equal
1987	January	³0.9	4 days	21	21.1	-0.1	Equal
1988	January	>0.9	3 days	3	2.6	0.4	Equal
1989	January	³0.9	3 days	55	33.8	11.2	Excess
1990	January	>0.9	1 days	6	0	6.0	Little excess
1991	January	0.9	1 day	10	0	10	Excess
1992	January	>0.9	2 day	50	25.5	24.5	Excess
1993	January	³0.9	4 days	20	10	10	Excess

Table 2-B: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	February	³0.8	4 days	40	53.4	-13.4	Less
1980	February	³0.9	2 days	10	6.2	3.8	Nearly equal
1981	February	>0.9	2 days	20	15.6	4.4	Nearly equal
1982	February	>0.9	5 days	25	17.2	7.8	Excess
1983	February	>0.9	3 days	15	5.2	9.8	Excess
1984	February	³0.9	5 days	30	15.5	14.5	Excess
1985	February	0.9	1 day	7	0.1	6.9	Excess
1986	February	³0.9	7 days	29	29.5	0.5	Equal
1987	February	>0.9	5 days	23	26.9	3.9	Equal
1988	February	>0.8	1 day	20	15.3	4.7	Nearly equal
1989	February	>0.9	3 days	5	0.8	4.2	Excess
1990	February	>0.9	8 days	105	73.7	31.3	Excess
1991	February	>0.9	3 days	30	24.6	5.4	Nearly equal
1992	February	>0.9	4 days	30	23.2	6.8	Excess
1993	February	>0.9	2 days	20	18.3	1.7	Equal

Table 2-C: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	March	0.9	3 days	15	17.8	-2.8	Nearly equal
1980	March	>0.9	4 days	30	31.7	-1.7	Equal
1981	March	³0.8	7 days	45	34.6	10.4	Excess
1982	March	>0.9	4 days	70	68.2	1.8	Equal
1983	March	>0.9	3 days	25	13.1	11.9	Excess
1984	March	>0.9	1 day	1	1.2	-0.2	Equal
1985	March	>0.9	1 day	1	1.1	-0.1	Equal
1986	March	0.9	3 days	15	12.8	2.2	Nearly equal
1987	March	³0.9	3 days	15	16.6	-1.6	Equal
1988	March	>0.9	3 days	45	30.2	15.2	Excess
1989	March	>0.9	2 days	15	15.8	-0.8	Equal
1990	March	³0.9	3 days	20	7.3	12.7	Excess
1991	March	>0.9	3 days	10	4.4	5.6	Excess
1992	March	>0.9	1 day	10	2.0	8	Excess
1993	March	>0.9	3 days	35	20.9	14.1	Excess

Table 2-D: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	April	0.8	1 day	5	3.2	1.8	Nearly equal
1980	April	>0.9	1 day	5	0.8	4.2	Excess
1981	April	³0.5	1 day	5	0	5	Excess
1982	April	³0.8	5 days	25	31.9	-6.8	Less
1983	April	>0.9	4 days	100	96.6	3.4	Equal
1984	April	0.9	4 days	4	4.6	-0.6	Equal
1985	April	0.9	3 days	10	6.3	3.7	Excess
1986	April	³0.8	2 days	2	2.3	-0.3	Equal
1987	April	0.9	1 day	10	7.5	2.5	Nearly equal
1988	April	³0.8	2 days	10	7.7	2.3	Nearly equal
1989	April	>0.9	2 days	6	2.1	3.9	Excess
1990	April	0.8	1 day	5	3.5	1.5	Nearly equal
1991	April	>0.9	2 days	20	20.4	-0.4	Equal
1992	April	>0.9	1 day	5	2.1	2.9	Nearly equal
1993	April	0.8	1 day	10	7.5	2.5	Nearly equal

Table 2-E: Comparison of simulated to observed precipitation

Year	Month	ERA simulated		Simulated precipitation (mm)	Observed precipitation (mm)	Difference (simulated to observed) (mm)	Magnitude of simulated precipitation w.r.t. to observed
		Cloud cover	No. of precipitation days				
1979	May	0.9	3 days	20	15.8	4.2	Nearly equal
1980	May	0.8	4 days	30	26.8	3.2	Nearly equal
1981	May	^{3}0.6	5 days	45	80.3	-35.3	Very less
1982	May	>0.9	1 day	50	35.3	14.7	Excess
1983	May	^{3}0.8	8 days	90	69.7	20.3	Excess
1984	May	0.9	1 day	1	0.3	0.7	Equal
1985	May	^{3}0.9	3 days	3	2.4	0.6	Equal
1986	May	0.5	4 days	40	39.2	0.8	Equal
1987	May	0.7	3 days	50	51.5	-1.5	Equal
1988	May	0.7	1 day	10	5.5	4.5	Excess
1989	May	^{3}0.9	2 days	2	0.4	1.6	Little excess
1990	May	0.6	4 days	20	27	-7.0	Less
1991	May	0.8	1 day	10	14.1	-4.1	Less
1992	May	>0.9	2 days	15	14	-1.0	Equal
1993	May	0.8	3 days	30	17.9	12.1	excess

Table 2-F: Comparison of simulated to observed precipitation

Year	Month	ERA simulated		Simulated precipitation (mm)	Observed precipitation (mm)	Difference (simulated to observed) (mm)	Magnitude of simulated precipitation w.r.t. to observed
		Cloud cover	No. of precipitation days				
1979	June	^{3}0.5	13 days	160	218.8	-58.8	Very less
1980	June	^{3}0.8	10 days	180	304.8	-124.8	Much less
1981	June	^{3}0.6	10 days	130	177.4	-47.4	Very less
1982	June	^{3}0.5	10 days	100	187.7	-87.7	Very less
1983	June	^{3}0.6	12 days	130	145.1	-15.1	Less
1984	June	^{3}0.6	5 days	70	55.3	14.7	Little more
1985	June	0.7	8 days	60	50.8	9.2	Little more
1986	June	0.7	8 days	90	80.0	10.0	Little more
1987	June	0.9	1 day	10	39.7	-29.7	Very less
1988	June	^{3}0.8	5 days	60	58.3	1.7	Equal
1989	June	^{3}0.8	4 days	32	37.0	-5.0	Less
1990	June	^{3}0.9	3 days	35	25.3	9.7	Little more
1991	June	^{3}0.6	5 days	60	74.9	-14.9	Less
1992	June	>0.9	2 days	20	25.6	-5.6	Less
1993	June	0.8	4 days	90	86.1	3.9	Equal

Table 2-G: Comparison of simulated to observed precipitation

Year	Month	ERA simulated		Simulated precipitation (mm)	Observed precipitation (mm)	Difference (simulated to observed) (mm)	Magnitude of simulated precipitation w.r.t. to observed
		Cloud cover	No. of precipitation days				
1979	July	^{3}0.9	16 days	250	244.8	5.2	Equal
1980	July	^{3}0.8	28 days	445	401.4	43.6	Large
1981	July	>0.9	14 days	255	249.5	5.6	Equal
1982	July	>0.9	10 days	195	187.1	7.9	Equal
1983	July	^{3}0.9	12 days	295	256.8	38.2	Excess
1984	July	^{3}0.9	21 days	215	175.8	39.2	Excess
1985	July	^{3}0.9	18 days	280	275.8	4.8	Equal
1986	July	^{3}0.9	17 days	85	73.4	11.6	Little excess
1987	July	0.8	5 days	35	21.3	13.7	Little excess
1988	July	^{3}0.9	22 days	390	286.7	103.3	Very large
1989	July	^{3}0.9	11 days	125	67.8	57.2	Excess
1990	July	^{3}0.9	17 days	275	230.3	44.7	Excess
1991	July	0.9	5 days	55	51.7	3.3	Equal
1992	July	>0.9	6 days	140	122.3	17.7	Little excess
1993	July	^{3}0.9	10 days	320	298.8	21.2	Little excess

Table 2-H: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	August	³0.9	10 days	100	66.7	43.3	Excess
1980	August	³0.9	11 days	210	219	-9.0	Less
1981	August	³0.6	25 days	340	376	-36.0	Less
1982	August	³0.4	31 days	450	573.4	-123.4	Very small
1983	August	³0.6	21 days	230	236	-6	Equal
1984	August	³0.9	23 days	163	189.1	-26.1	Less
1985	August	³0.9	20 days	200	173.8	26.2	Excess
1986	August	0.9	13 days	160.2	100.7	59.5	Large
1987	August	³0.9	8 days	85	70.3	4.7	Equal
1988	August	0.7	23 days	230	217.5	12.5	Excess
1989	August	³0.9	11 days	155	109.1	45.9	Large
1990	August	³0.9	19 days	155	115.7	39.3	Excess
1991	August	³0.9	14 days	230	178.8	61.2	Large
1992	August	>0.9	15 days	225	187.8	47.2	Large
1993	August	³0.9	8 days	40	46.8	-6.8	Equal

Table 2-I: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	September	³0.5	10 days	60	162.3	-102.3	Very small
1980	September	³0.6	8 days	85	330.6	-285.6	Very small
1981	September	³0.5	15 days	125	291.4	-166.4	Very small
1982	September	³0.6	12 days	110	125.8	-15.8	Less
1983	September	³0.5	24 days	280	299.5	-19.5	Less
1984	September	0.9	8 days	95	76.5	18.5	Little excess
1985	September	0.8	4 days	35	32.9	2.1	Equal
1986	September	0.6	7 days	50	52.1	-2.1	Equal
1987	September	0.8	3 days	12	11.1	0.9	Equal
1988	September	³0.5	14 days	180	223.2	-43.2	Less
1989	September	0.8	2 days	2.	19.7	0.3	Equal
1990	September	0.8	13 days	180	178.5	1.5	Equal
1991	September	³0.9	5 days	50	40	10	Little excess
1992	September	³0.9	5 days	50	55.3	-5.3	Equal
1993	September	>0.9	7 days	180	137.2	42.8	Excess

Table 2-J: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	October	>0.9	1 day	5	47.8	-42.8	Very small
1980	October			0	92.8	-92.8	Very small
1981	October	³0.7	2 days	10	12.9	-2.9	Equal
1982	October	³0.5	7 days	40	44.3	-4.3	Equal
1983	October	³0.5	5 days	35	91.2	-56.2	Very small
1984	October			0	0	0	Equal
1985	October	>0.9	4 days	50	28.0	22	Excess
1986	October	0.6	2 days	10	10.9	-0.9	Equal
1987	October	0.7	2 days	2	2	0	Equal
1988	October			0	0	0	Equal
1989	October			0	1.2	-1.2	Equal
1990	October			0	12.6	-12.6	Less
1991	October			0	0	0	Equal
1992	October	0.8	1 day	5	3.2	1.8	Equal
1993	October	0.8	1 day	1	0	1.0	Equal

Table 2-K: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	November	0.9	2 days	10	0.6	9.4	Excess
1980	November	>0.9	1 day	5	4.8	0.2	Equal
1981	November	>0.9	1 day	10	49.1	-39.1	Very small
1982	November	>0.9	2 days	5	2.4	2.6	Little excess
1983	November			0	0	0	Equal
1984	November	0.8	2 days	2	0	2.0	Equal
1985	November			0	0	0	Equal
1986	November	³0.9	4 days	4	1.0	3	Excess
1987	November			0	0	0	Equal
1988	November	0.7	1 day	0	0.3	-0.3	Equal
1989	November	>0.9	1 day	10	7	3	Equal
1990	November	³0.9	3 days	15	16.9	-1.9	Equal
1991	November	0.8	1 day	5	3.4	1.6	Equal
1992	November	>0.9	1 day	20	11.7	8.3	Excess
1993	November			0	1.2	-1.2	Equal

Table 2-L: Comparison of simulated to observed precipitation

Year	*Month*	*ERA simulated*		*Simulated precipitation (mm)*	*Observed precipitation (mm)*	*Difference (simulated to observed) (mm)*	*Magnitude of simulated precipitation w.r.t. to observed*
		Cloud cover	*No. of precipitation days*				
1979	December	>0.9	1 day	15	5.6	9.4	Excess
1980	December	>0.9	3 days	25	27.2	-2.2	Equal
1981	December	>0.9	1 day	1	0.8	0.2	Equal
1982	December	>0.9	1 day	20	11.1	8.9	Excess
1983	December	>0.9	5 days	15	9.4	5.6	Little excess
1984	December	>0.9	1 day	0	0.3	-0.3	Equal
1985	December	³0.9	6 days	35	27.7	7.3	Little excess
1986	December	>0.9	2 days	10	9.1	0.9	Equal
1987	December	>0.9	2 days	10	5.4	4.6	Little excess
1988	December	³0.9	3 days	21	9.8	11.2	Excess
1989	December	>0.9	3 days	20	14.4	5.6	Excess
1990	December	>0.9	6 days	40	23.3	16.7	Large
1991	December	³0.9	3 days	50	30.3	19.7	Large
1992	December	—	—	0	0.1	-0.1	Equal
1993	December	>0.9	2 days	5	0	5.0	excess

In the present study, the dates of monsoon rainfall occurrence as shown in the power fit and exponential fit almost coincide with the observations and news reports during July and August during the years 2002, 2003, 2004 and to some extent in 2005. It is really interesting to note that the dates in the months of July (3, 5, 13, 15, 16, 25, 27, 28, 29, 30) August (2, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 19, 21, 22, 25) and September (1, 2) are exactly coinciding with the observed rainfall spells over Haryana during Indian monsoon season. However there is a deviation from these dates are found during the year 2005. In September 2005 the rainfall occurred over Haryana is Maximum and number of rainy days are also more.

5. CONCLUSIONS

In climate or climatology studies the need for the study of less emblematic parameters like cloud cover and precipitation patterns generated by global climate models and reanalysis is increasing in terms of its exclusive documentation. For monitoring the climate change, temporal consistent data sets are extremely important. The spatial and temporal distribution of precipitation is of most vital interest. Efforts are made by several groups to obtain precipitation data by incorporating gauge measurements, satellite sounding and model based consistent forecast data to close the gaps that can not be filled by conventional or satellite observations. ECMWF is working towards an extensive new reanalysis which could begin in late 2008 or later. Major changes are to the forecasting system are being made to improve the representation of the hydrological cycle. Assimilation of satellite radiances affected by high clouds is being prepared which should improve the quality of upper tropospheric humidity in cloud systems. In Indian context, NCMRWF also provides the 2-3 day short range forecasts to help the agriculture sector. So a perfect balance between forecasts of numerical weather prediction models and augmentation of real time satellite data give a significant match for the planning and protection of global hydrological cycle.

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