Development of the Monsoonal Asia Climate Risk Analysis Maprooms

Working Paper No. 233

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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James Hansen

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Abstract

The Asian monsoon plays a major role in the variability of seasonal temperature and precipitation and the sub-seasonal statistics of these and other climate variables. Due to its considerable impact on the quality and quantity of agricultural output, there is an essential need for greater understanding of the historical risk associated with the Asian monsoon, with the ultimate goal being better climate risk analysis to support agricultural decision-making in South and Southeast Asia. In response to partner demand expressed by the CCAFS South Asia Regional Program, CCAFS worked with the International Research Institute for Climate and Society (IRI) to develop a suite of online Maproom tools for analyzing agriculturally important aspects of climate variability, based on gridded historical daily precipitation and temperature data. This report documents the rationale, development, and use of the Monsoon Asia Historical Precipitation and Temperature Monitoring Maprooms. These tools aim to provide enough flexibility to support a demanding range of analysis and decision support needs. The weather factors that impact agriculture, and the analyses that are needed to support agricultural decision-making, vary considerably by location, production system and time of year. These Maprooms serve as the precursors to the Daily Climate Analysis Maprooms that was developed later.

Keywords

Monsoon; analysis; statistic; precipitation; temperature; Maprooms

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Introduction

Year-to-year variability in growing season weather conditions, driven in part by the Asian Monsoon system, exposes agriculture to a high degree of risk. This is particularly true for smallholder farming in marginal rainfed environments. Extreme events, such as droughts, flooding and heat waves, lead to loss of crops, livestock and farmer livelihoods. Even in years with favorable climatic conditions, the resulting uncertainty is a disincentive to investment in agriculture and adoption of available production technology.

In response to partner demand expressed by the CCAFS South Asia Regional Program, CCAFS worked with the International Research Institute for Climate and Society (IRI) to develop a suite of online Maproom tools for analyzing agriculturally important aspects of climate variability, based on gridded historical daily precipitation and temperature data.

The design of these tools aims to provide enough flexibility to support a demanding range of analysis and decision support needs. The weather factors that impact agriculture, and the analyses that are needed to support agricultural decision-making, vary considerably by location, production system and time of year. Furthermore, we anticipated that farmers, their advisors and other local decision-makers would need location-specific analyses, while governments and institutions working at an aggregate scale would likely be interested in spatial patterns of risk. Finally, many of the meteorological risks that are important for agriculture cannot be characterized adequately by season average conditions, but require analyses based on daily time series data. Harvest yields are sensitive to the dynamic interactions between crop phenology, the impact of daily precipitation and evapotranspiration on the soil water balance, and the timing of temperature or water stress.

This report describes the development and main features of the resulting Monsoonal Asia Climate Risk Analysis Maproom, provides guidance on navigating its interface and presents two hypothetical examples that illustrate potential for decision support applications. The development of the Monsoonal Asia Climate Risk Analysis Maproom, in 2013-2014, followed and built on earlier development of an online Maproom to support spatial analysis of seasonal rainfall predictability across South Asia, to inform the development of downscaled seasonal forecast systems (Robertson et al., 2013).

Maproom Features

The Monsoon Asia Historical Precipitation and Temperature Monitoring Maprooms allows for the calculation of different statistics based in historical daily precipitation and temperature data. Some examples of the rainfall statistics include the historical probability of receiving less than a specified number of rain days within a growing season and the historical risk of dry spells (of user-chosen durations) within a critical crop stage. Statistics for temperature include heating degrees days (accumulated deficits between the mean daily temperature and a user-defined reference temperature during the season), and the number of cold and hot days relative to a user-defined threshold. The user can visualize these statistics and other results in a map grid and also check the historic observations for one specific grid box.

The Monsoon Asia Historical Precipitation Maproom can be accessed online at http://iridl.ldeo.columbia.edu/maproom/Agriculture/Historical_Monitoring/SouthAsia_Precip.html and the Monsoon Asia Historical Temperature Maproom at http://iridl.ldeo.columbia.edu/maproom/Agriculture/Historical_Monitoring/SouthAsia_Temp.html.

Underlying data

The Monsoon Asia Historical Precipitation and Temperature Monitoring Maprooms make use of the Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of the Water Resources (APHRODITE) daily rainfall dataset (1951– 2007) (Xie et al., 2007) and interpolated temperature dataset (1973-2007) (Yasutomi et al., 2011) of monsoon Asia (15°S-55°N, 60°E-155°E). APHRODITE datasets were created in collaboration with Research Institute for Humanity and Nature and Meteorological Research Institute of Japan Meteorological Agency. The 0.5x0.5 and 0.25x0.25-degree gridded precipitation suite (version: V1003R1) was derived from original rain-gauge data, precompiled datasets, and global telecommunication system reports. The temperature suite (version: V1204R1), also at the same resolution, was developed by utilizing the collection of observed temperature data.

Derived variables

The Maprooms provide analysis of several variables, derived for user-specified time windows from gridded daily time series data, that are relevant to agriculture. In rainfed production, crop yields are a function of dynamic, nonlinear interactions between daily rainfall, the soil water balance and crop growth stage. The soil water balance, and hence water available to the crop, is sensitive to the distribution of rainfall within the growing season. In addition to total rainfall in a user-selected window, the Monsoon Asia Historical Precipitation Monitoring Maproom provides several higher-order statistics of rainfall that affect the soil water balance and hence the soil's ability to meet crop water requirements: rainfall intensity, number of rain days, and number of dry and wet spells of a user-selected length. Disaggregating total rainfall during a particular time of year into frequency of rain days and mean intensity on rain days provides an indication of how much observed year-to-year variability is due to the frequency of storms versus the intensity of storms. Setting the dry spells for periods that are long enough to deplete soil water in the root zone is often used an indicator of risk of crop water stress (Sivakumar, 1992; Stern & Cooper 2011; Barron et al., 2003). The intensity of rainfall influences how much rainfall infiltrates the soil, risk of soil erosion, and nutrient movement within the soil (Dourte et al., 2015).

The Monsoon Asia Historical Temperature Monitoring Maproom provides analysis of number of cold days below a threshold, number of hot days above a threshold, growing degree days, and chilling degree days. Frequency of hot and cold extremes relative to user-selected thresholds is included because of the negative impact that temperature extremes can have on crop yields and on livestock health. The concept of thermal time, expressed as has the accumulation over time of temperature relative to a baseline, multiplied by the amount of time the temperature is above or below this baseline, is used extensively for analyzing crop phenology (Trudgill et al., 2005). Growing degree-days, defined as the thermal time above a crop-specific baseline temperature and summed across days from the time of germination, is a widely used predictor of time to flowering and maturity, for crops that are not sensitive to daylength and do not require cold temperatures to stimulate flowering (McMaster & Wilhelm, 1997; Li et al., 2012). A number of crops, including winter wheat and many deciduous fruit species, require an accumulation of chill units to stimulate flowering (Luedeling, 2012). Chill units are analogous to growing degree days but are typically expressed in unites of degree-hours below a crop-specific threshold temperature. Analyses of thermal time and damaging extreme temperature events are normally based on daily minimum and maximum temperature, or data at a higher temporal resolution, to account for the important diurnal variations in temperature. Thermal time calculations were simplified to use daily averages because APHRODITE gridded daily temperature data was only available as a daily average. The resulting bias could be substantial relative to thermal time calculations that account for the diurnal temperature range.

Table 1: Derived precipitation variables, definition and user-selected thresholds within the Monsoon Asia Historical Precipitation and Temperature Monitoring Maprooms

	Variable	Definition	User thresholds
		Precipitation	
1	Total Rainfall	Total cumulative precipitation falling over a specific season	
2	Rainfall Intensity	Total rainfall divided by number of wet days	
3	Number of Wet Days	The number of days when rainfall exceeds a specified threshold amount	Minimum daily rainfall threshold (mm)
4	Number of Wet Spells	The number of continuous spells at least as long as a specified minimum duration, with rainfall exceeding a specified threshold amount every day during the season. If a wet spell is defined as 5 contiguous wet days, 10 contiguous wet days are counted as 1 wet spell. A wet spell that overlaps the start or end of the season will be counted only if the part of the spell that falls within the season reaches the minimal length.	Minimum daily rainfall threshold (mm); Minimum spell duration (days)
5	Number of Dry Spells	The number of continuous spells at least as long as a specified minimum duration, with no days having receiving more than a specified threshold amount.	Minimum daily rainfall threshold (mm); Minimum spell duration (days)
		Temperature	
6	Number of Cold Days	The number of cold days during the season according to the user-defined cold day threshold and according to the mean daily temperature.	Maximum temperature considered cold (°C)
7	Number of Hot Days	The number of hot days during the season according to the user-defined hot day threshold and according to the mean daily temperature.	Minimum temperature considered hot (°C)
8	Chilling Degree Days	Summations of negative differences between the mean daily temperature and user-defined cold day during the season.	Maximum temperature considered cold (°C)
9	Growing Degree Days	Summations of positive differences between the mean daily temperature and user-defined hot day during the season.	Minimum temperature considered hot (°C)

Selection of Time and Spatial Domain

The user has the ability to specify the range of years over which to perform the analysis and choose the start and end dates of the season (e.g. Jan 1-Jun 15) over which the diagnostics are to be performed. All Maproom results and statistics (total rainfall, number of cold days, etc.) shown will be associated with these years and season. The Maproom will then default to displaying the entire monsoon Asia (15°S-55°N, 60°E-155°E) map. To select a more specific region, the user can draw a rectangle with the left click of the mouse on top of the map and select that region (i.e. click, drag and release).

Visualization of Results

After the selection of the aforementioned variables, a map view presents the variables selected for the chosen season and range of years produces maps. Users can view the results spatially as either the mean, the standard deviation, probability of exceeding a user specified threshold, coefficient of variation (ratio of standard deviation to the mean) in percentage, or percentile of historical distribution (e.g., 0.1, 0.25, 0.5, 0.75 and 0.9). After a map has been generated, the user has the ability to click on any point on the map in order to create a timeseries line graph for that specific location. The timeseries graph—which captures the years, season, and seasonal variable previously selected—provides pixel-scale information about climate variability and trends.

Maproom Examples

Analyzing Drought Risk (Number of Dry Spells) in Bangladesh

A majority of Bangladesh's agricultural output is grown under rain-fed conditions. In addition to the absence of irrigation infrastructure, there has been increase in drought incidence and intensity during the last decades in the country (Hossain, 2013). Therefore, drought risk is an important issue for the agriculture sector. An example of the assessment of drought risk in Bangladesh is illustrated in Figure 1-3. Figure 1 shows the parameters have been selected within the Monsoon Asia Historical Precipitation Monitoring Maproom to reflect the mean number of historical dry spells from 1951-2007 during a selected planting season, April 1-30, with thresholds for a dry spell as a 5-day period with less than 1 mm of rain.

The brown shaded areas on the Figure 2 indicates a historic average of zero dry spells in the month of April, while the light green shaded areas indicate two dry spells. According to these results, an April planting/sowing season may be better in the northeastern region of Bangladesh where there where it is historically less likely of having a dry spell.

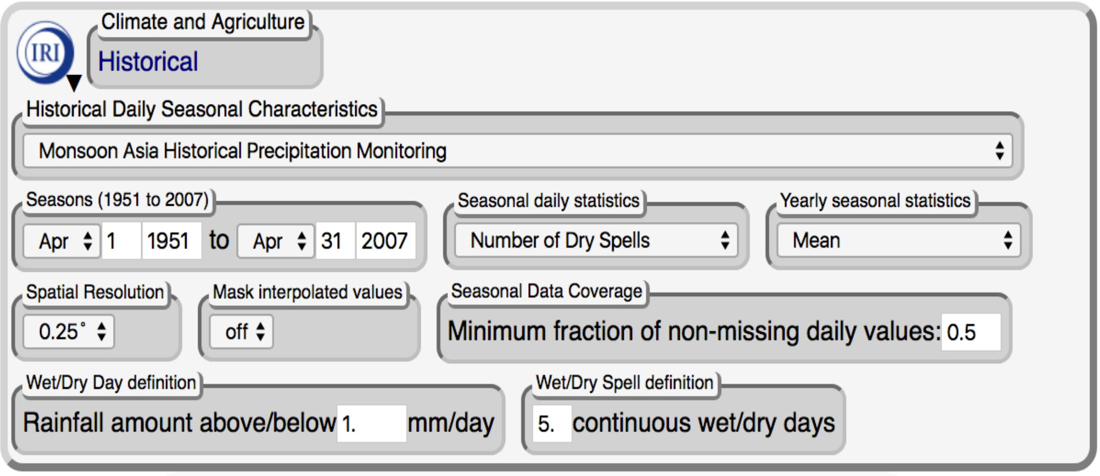


Figure 1: Maproom parameter setting for mean number of Dry Spells in Bangladesh during the season of April 1-31 from 1951-2007

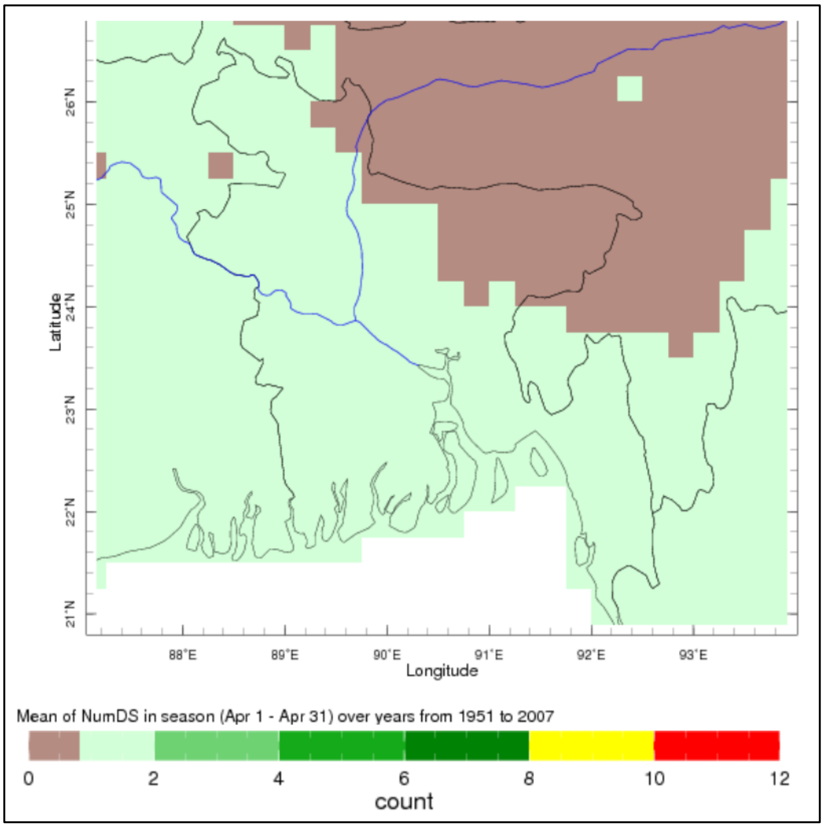


Figure 2: Generated map of Bangladesh, using rectangular zoom function to display mean number of Dry Spells in Bangladesh during the season of April 1-31 from 1951-2007

Figure 3 also displays the 1951-2007 time series of the number of April 1-30 dry spells at the coordinates 90.25°E-90.5°E, 23.5°N-23.75°N – a location very near the capital of Dhaka. Although the average number of dry spells for Dhaka is two, there are some noteworthy years that exceeded the mean, particularly in April of 1980 when there were four.

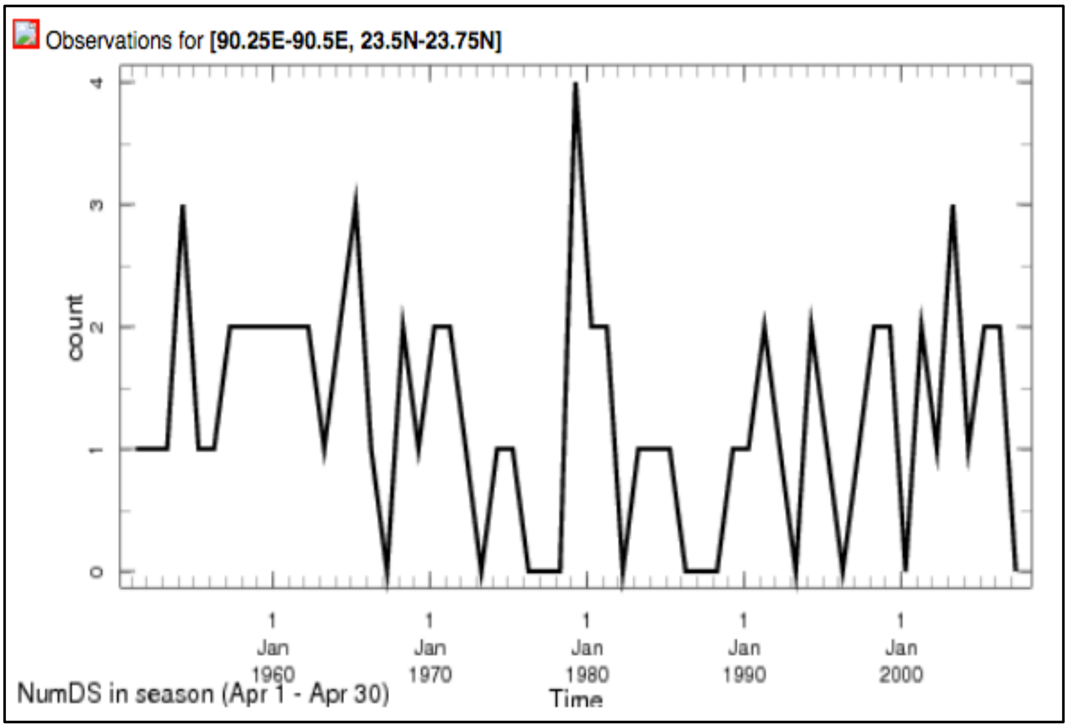


Figure 3: 1951-2007 time series of the number of April 1-30 dry spells at the coordinates 90.25°E-90.5°E, 23.5°N-23.75°N (a location very near the capital of Dhaka)

Analysing Heat Risk (Number of Hot Days) in India

Some Indian crops (e.g. rice) are adversely affected by high temperatures. Heat stress during their growth development, in particular the ripening stage, can reduce the total production of the crop. An example of the assessment of heat risk in India is illustrated in Figures 4-6. Using the Monsoon Asia Historical Temperature Monitoring Maproom, parameters were set to reflect and assess the number of hot days with a threshold above 29°C during a may be selected season of March 15 to May 15 as seen in the top portion of Figure 4.

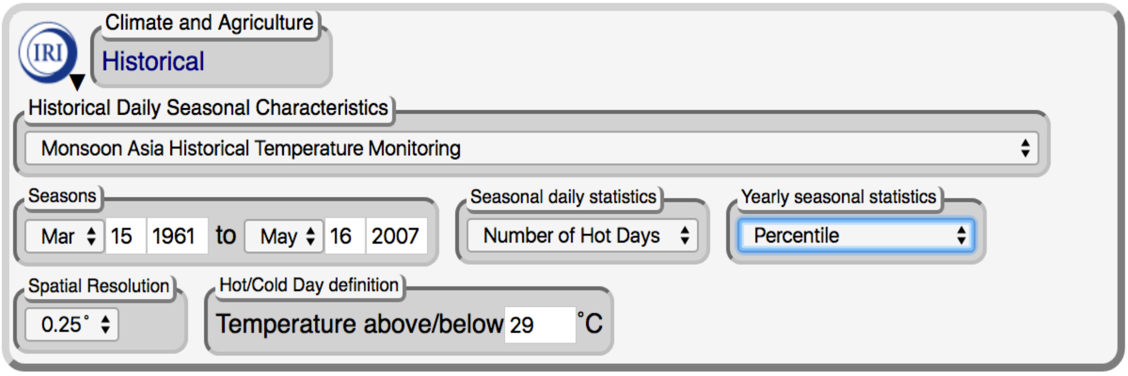


Figure 4: Maproom parameter setting for Number of Hot Days and percentiles in Odisha, India during the season of March 15 – May 15 of 1961-2007

The two maps (Fig. 5) have been adjusted to encompass the eastern region of India where the state of Odisha is located (approximate coordinates are 16-20°N latitude and 80-86°E longitude). As seen from these maps and the 0.1 (left) and 0.9 (right) historic distribution levels (Fig. 5), periods of 20-30+ hot days stretch across most of Odisha during the March 15 to May 15 season, with the southwestern tip having periods of 40+ hot days during the 1961-2007 timeseries.

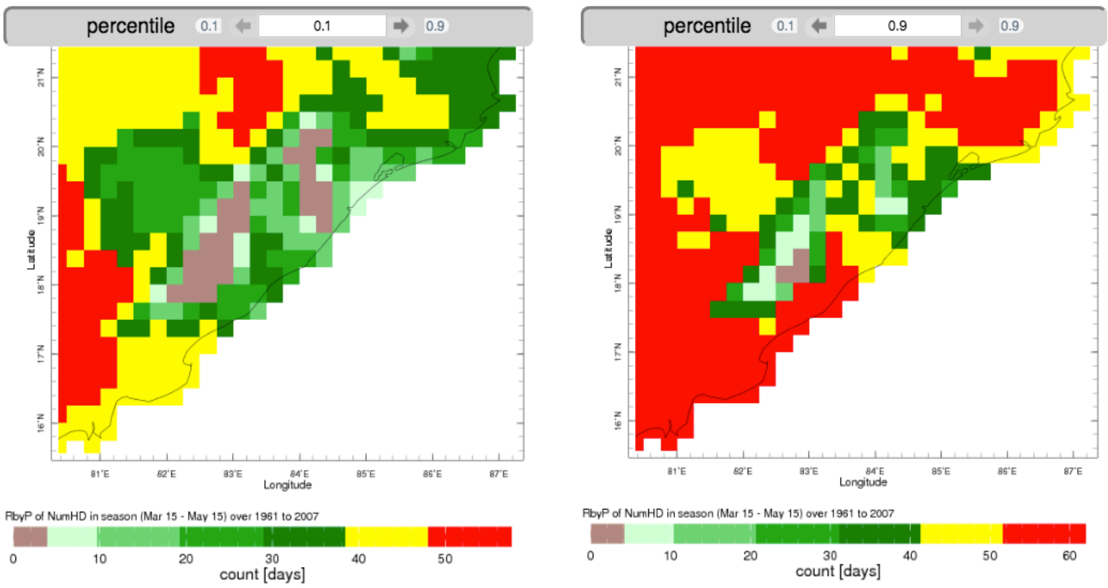


Figure 5: Map display of Number of Hot Days in Odisha, India at the 0.1 and 0.9 percentiles (maps) during the season of March 15 - May 15 of 1961-2007

This is further illustrated by the time series graph (Fig. 6) which depicts 42+ hot days in a southwestern coastal town of Odisha at 80.5°E-80.75°E, 16°N-16.25°N each season of each year. The flexibility of the Maproom allows one to explore, for example, whether adjusting the planting date might lessen the exposure to heat risk during a critical development phase.

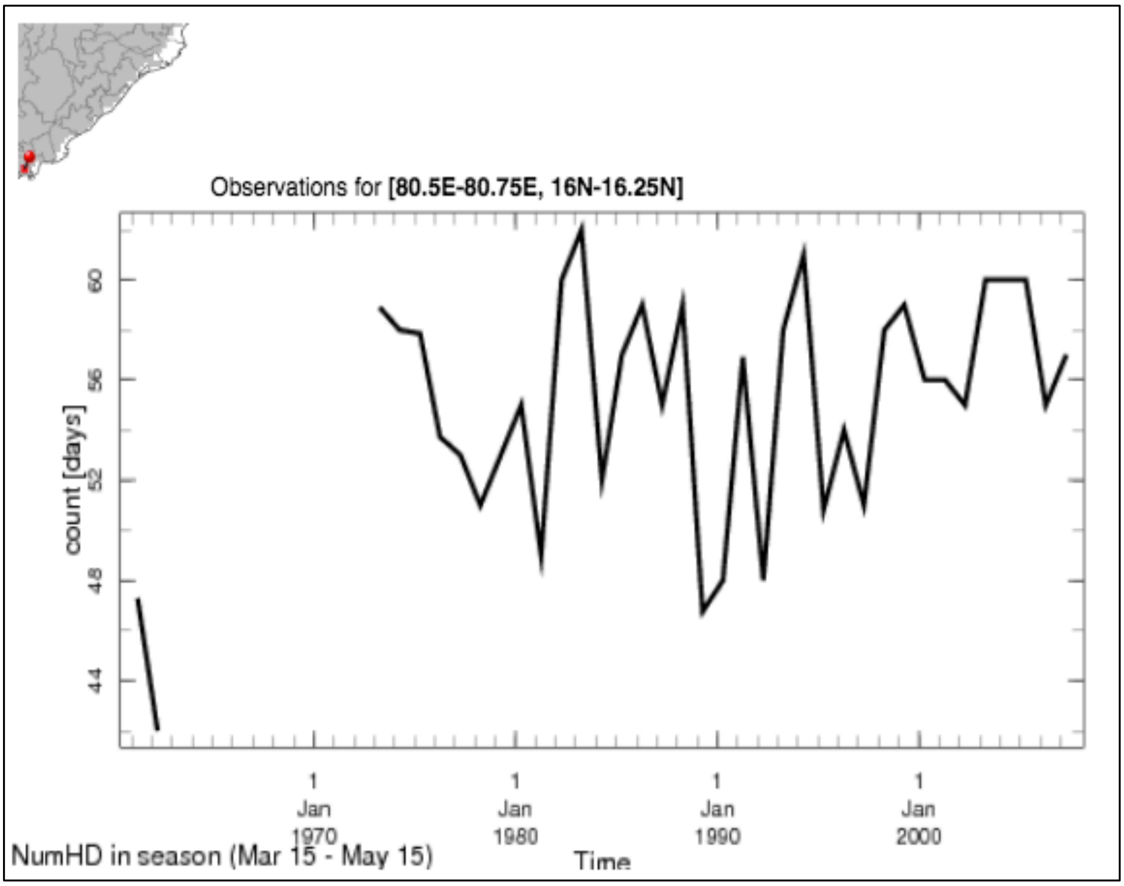


Figure 6: Timeseries of the Number of Hot Days a southwestern coastal town of Odisha during the season of March 15 – May 15 of 1961-2007

Conclusion

The Monsoon Asia Historical Precipitation and Temperature Monitoring Maproom tools, built on the IRI's Data Library platform, were designed to support analysis of APHRODITE gridded meteorological data from an agricultural risk perspective within CCAFS Asia regional programs. Their flexible menu interface gives users considerable control over variables of interest, time and geographical domains, and statistics for spatial display. They provide both a spatial view, and local time series graphs, anticipating that governments and institutions working at an aggregate scale would likely be interested in spatial patterns of risk, while farmers, their advisors and other local decision-makers would need location-specific analyses. These Maprooms also serve as the precursor to Daily Precipitation Climate Analysis Maprooms that have been implemented by National Meteorological services in the African countries of Senegal, Mali, Ethiopia, Rwanda, and Madagascar, and by regional climate centers in East (ICPAC) and West (AGRHYMET) Africa.

Appendix: Navigating the Maproom Interface

Main elements of the Maproom

Figure A1 shows the general view for the Maproom, including a description of the main elements of the user´s interface.

The first thing you need to do is set the parameters in the upper portion of the screen (blue box in Figure A1), we will see how to do this in detail in the next section. Once you have defined the season and the desired statistic, the map will change accordingly.

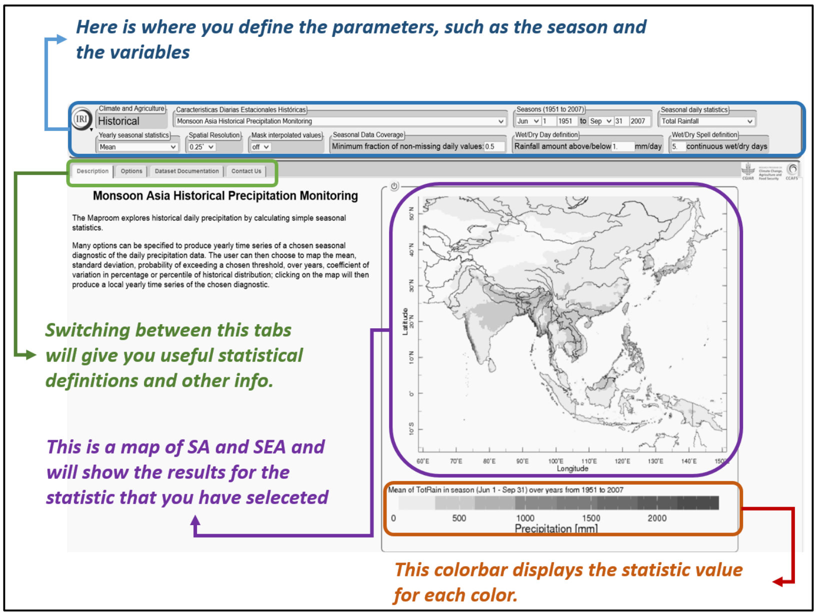
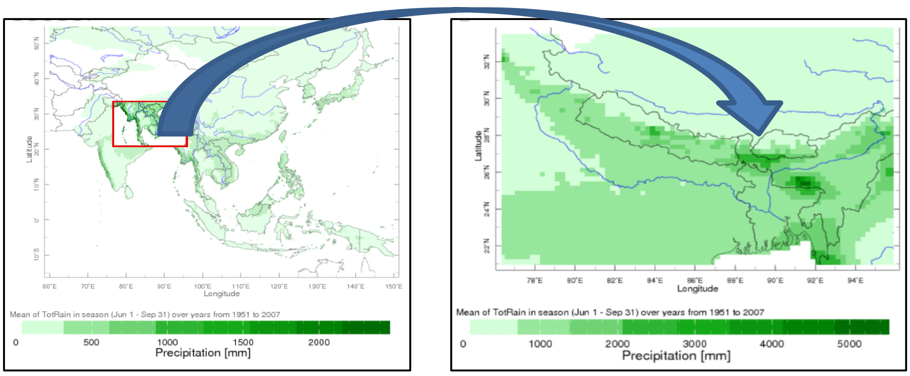


Figure A1. Maproom general view and description.

In addition, if you want to check a more specific region, you can draw a rectangle with the left click of the mouse on top of the map and select that region (click, drag and release), as it is shown in Figure A2.



Drawing a rectangle with your mouse will allow you to zoom up to any region you want to assess

Figure A2. Illustration regarding the selection of specific areas in Maproom.

Notice that if you move the cursor to the left top corner of any map, the Maproom gives you more options that you can explore, such as downloading or sharing your map on social networks and select the layers you want to display on the map (borders, lakes, rivers etc.). A detail of this is shown in figure A3.

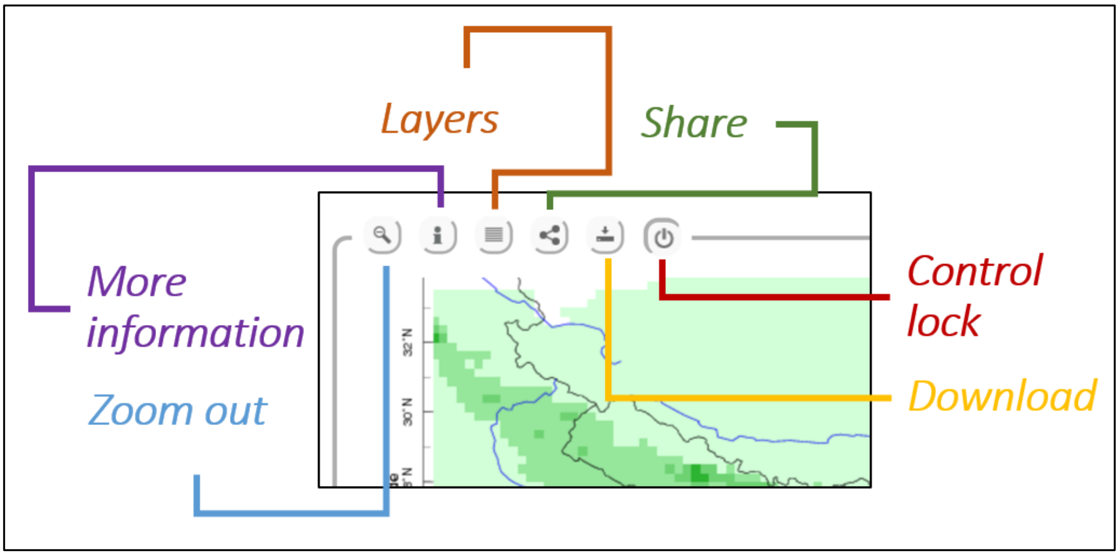


Figure A3. Available options to manage the map in Maproom.

Setting the parameters

In order to calculate and visualize historical statistics, the first thing you need to do is define the season you want to assess, the type of event (total rainfall, number of dry/wet spell, etc.) and the statistic (mean, standard deviation, percentile, etc.). Although the parameters definition is very similar in both the precipitation and temperature Maprooms, they are slightly different. Therefore, a detailed explanation has been made for each of them separately.

Precipitation Maproom parameters

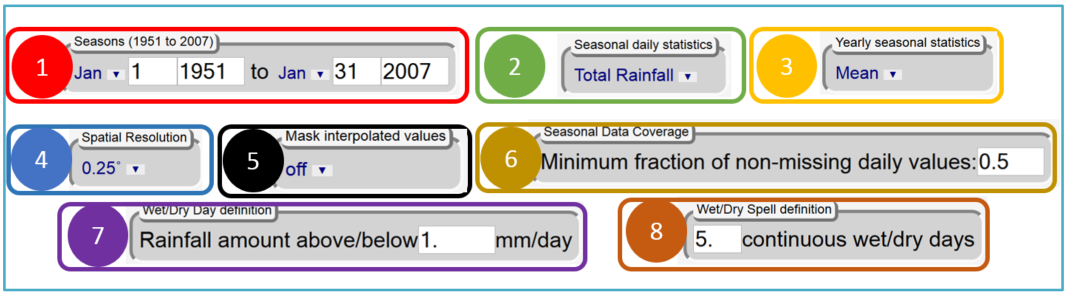


Figure A4. Parameters in Maproom. Numbers have been added for explanation purposes.

Figure A4 shows a screenshot of the parameters section you will find in a Maproom. As you see, there are 8 editable boxes. A number and color has been added in this figure for explanation purposes. It is important to understand what each of these parameters mean, because the results Maproom shows will depend on the numbers you plug in in each of these boxes. Bear in mind that the numbers you plug in boxes 1 to 6 are important for any statistic computed, while boxes 7 and 8 will only be relevant when wet and dry spells are computed. The following table has a specific description of what each of the boxes is. A more precise explanation for some of the concepts presented in this table is discussed in section 3 of this guide.

Table A1. Description of Precipitation Maproom parameters.

Box number	Description
1	***Seasons***: There are two important things the user needs to define here. The first one is the season ***within the year*** you want to assess. You do this by choosing a starting and ending day and month (e.g. Jan 1-Jun 15). All the results shown by Maproom will be associated with this interval of time (total rainfall over the period, number of cold days etc.). The second parameter you need to define here is the beginning and ending year. The Maproom will use the data gathered between those years to compute the corresponding statistic.
2	***Seasonal daily statistic:*** Here is where you choose what type of event you want to focus on. Among the options you have: total rainfall, number of wet days, mean rainfall intensity, number of dry spells, number of wet spells. Here you can also check the percentage of data available for the period you chose.
3	***Yearly seasonal statistic:*** Maproom will take all the available data from all years specified in Box 1 and will then compute a specific statistic considering the season you have chosen (e.g Jan 1- Jun 15). Here is where you select what interannual statistic you want Maproom to compute: Mean, Standard Deviation, Probability of exceeding, Coefficient of Variation, and Percentile of the distribution of years.
4	***Spatial resolution:*** The analysis can be performed and mapped at each grid point for both 0.25˚ and 0.50˚. Here is where you decide at what resolution results will be computed.

5	***Mask interpolated values:*** When periods of historical observations are missing, the Maproom can fill in these missing data by using a temporal interpolation method. Here is where you decide to use the interpolation or not, by also defining -in Box 6- what fraction of non-missing daily values are you willing to consider.
6	***Minimum fraction of non-masked days per season:*** As described in Box 5, a minimum fraction of non-masked days per season can be required in order for the seasonal diagnostic to be defined at that gridbox — if this minimum threshold is not met, then the seasonal diagnostic is assigned a missing value at that gridbox, for that season and year.
7	***Wet/dry day definition:*** This parameter is only relevant when you want Maproom to compute the number of wet days or number of dry/wet spells. Here is where you define the threshold (in mm) for what you want to consider as a dry day (rainfall below), or a wet day (rainfall above).
8	***Wet/dry spell definition:*** This parameter is only relevant when you want Maproom to compute the number of dry/wet spells. Here is where you define the number of continuous wet/dry days. The definition for what is a wet/dry day is defined in Box 7.

Temperature Maproom parameters

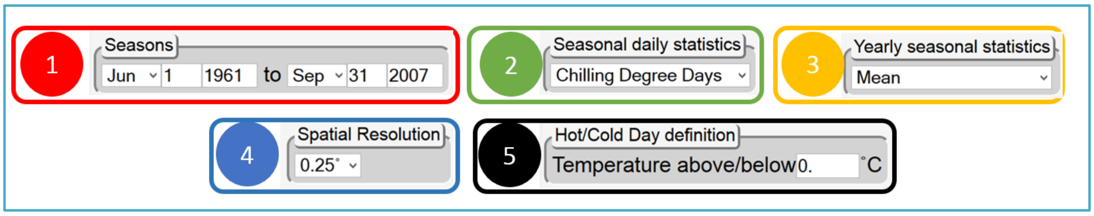


Figure A5. Parameters in Maproom. Numbers have been added for explanation purposes.

Figure A5 shows the parameters that need to be defined by the user in the Temperature Maproom. If you already checked the previous section, you will see that the only different thing here with respect to the Precipitation Maproom, are the seasonal daily statistics. Some of the interannual temperature statistics are also different from precipitation. This is explained in detail in Table 2 below.

Table A2. Description of Temperature Maproom parameters

Box number	Description
1	***Seasons***: There are two important things the user needs to define here. The first one is the season ***within the year*** you want to assess. You do this by choosing a starting and ending day and month (e.g. Jan 1-Jun 15). All the results shown by maproom will be associated to this period of time (total rainfall along that period, number of cold days etc.). The second parameter you need to define here is the beginning and ending year. Maproom will use the data gathered between those years to compute the corresponding statistic.

2	***Seasonal daily statistic:*** Here is where you choose what type of event you want to assess. Among the options you have: chilling degree days, number of hot days, number of cold days, growing degree days.
3	***Yearly seasonal statistic:*** Maproom will take all the available data from all years specified in Box 1, and will then compute a specific statistic considering the season you have chosen (e.g Jan 1- Jun 15). Here is where you select what statistic you want Maproom to compute: Mean, Standard Deviation, Coeficient of Variation and Percentile.
4	***Spatial resolution:*** The analysis can be performed and map at each grid point for both 0.25˚ and 0.50˚. Here is where you decide at what resolution results will be computed
5	***Hot/cold day definition:*** This parameter is only relevant when you want maproom to compute the number of hot days or cold days. Here is where you define the threshold for what you want to consider as a hot or a cold day.

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