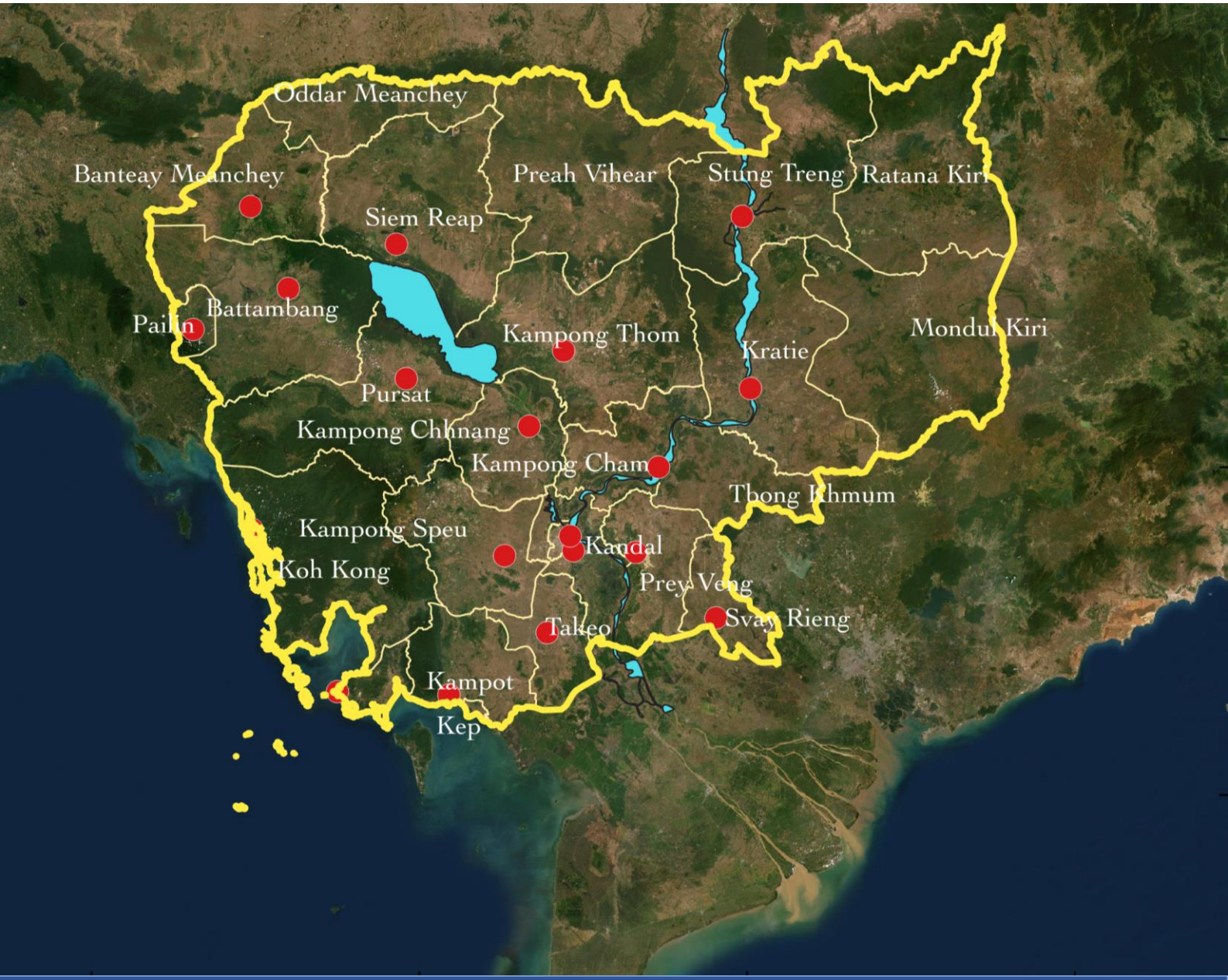

Proposed Climate Zone for Cambodia

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UNDP

Regional Integrated Multi-Hazard Early Warning System
RIMES

Strengthening Climate Information and Early Warning Systems in Cambodia

Proposed Climate Zone of Cambodia

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Suggested reference:
RIMES and UNDP (2020), Proposed Climate Zone of Cambodia, Strengthening Climate Information and Early Warning System in Cambodia, Regional Multi-Hazard Early Warning System for Asia and Africa (RIMES) and United Nations Development Programme (UNDP).

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1. Background

United Nations Development Programme (UNDP) partnered with Regional Integrated Multi Hazard Early Warning System to implement the project "Strengthening early warning system in Cambodia to support climate-resilient development and adaptation to climate change", in close cooperation with Department of Meteorology and Department of Hydrology, Cambodia. One of the objective of the project is to build capacity of Department of Meteorology (DOM) to generate climate information at different timescales using Numerical Weather Prediction model and long-range statistical models. The generation of long-range seasonal outlook is reliable when it is prepared for climatological zones rather than the administrative zones. Since there is no climatological zone map available for Cambodia, RIMES and DoM jointly undertook an assessment with climate data from surface observatories and satellite based estimates to prepare the climate zone map for Cambodia. The main purpose of carrying out this activity is to generate the climate zone map, which would be used for generating seasonal forecast at climate-zone level, as the climate models predictability skills increase when the long lead forecasting by climate zone-wise. This report summarizes the data used, approach followed especially for spatial and temporal analysis of climate data, rationale for delineating climate zones.

2. Approach

2.1 Data

Climate data for 19 surface observatories were obtained from Department of Meteorology for the period 1980-2017 (Figure-1, Table-1). Rainfall data was available for all 19 stations, whereas temperature data was only available for 15 stations. The data were quality checked and found all the observatories were having more than 95% of datasets. The spatial coverage of the surface observatories were not sufficient, for instance, the following provinces were not having any surface observatories: Rattanakir and Mondulkiri, Preah Vihear, Otdar Mean Chey. To overcome the data limitation, Satellite based rainfall and temperature estimates were used. Rainfall estimates from NASA's Global Precipitation Measurement (GPM) at 0.1 degree spatial resolution for the period 2000-2019 were downloaded using NASA Earth data portal – *GIOVANNI* [1] tool. The downloaded GPM data were analysed to validate against the observation and also to understand the spatial variability of rainfall within Cambodia. For understanding spatial variation of temperature parameter, Moderate Resolution Imaging Spectroradiometer (MODIS) MOD11C3 v006 Land Surface Temperature (LST) available at two variant (day and night) at 0.05 degree spatial resolution for the period 2000-2019 were used. MODIS data was obtained from *GIOVANNI* tool[2]. The mean temperature was calculated for all the months by averaging day and night temperature, and annual average was calculated by averaging all the months for every year and then for all years together. Apart from the rainfall and temperature parameter, topography data from Shuttle Radar Tropical Mission (SRTM) at 30m spatial resolution was used (Figure-2).

[1] https://giovanni.gsfc.nasa.gov/giovanni/#dataKeyword=IMERGM
[2] https://giovanni.gsfc.nasa.gov/giovanni/#service=TmAvMp&starttime=&endtime=&dataKeyword=LST/).

Figure 1. Surface observatories in Cambodia

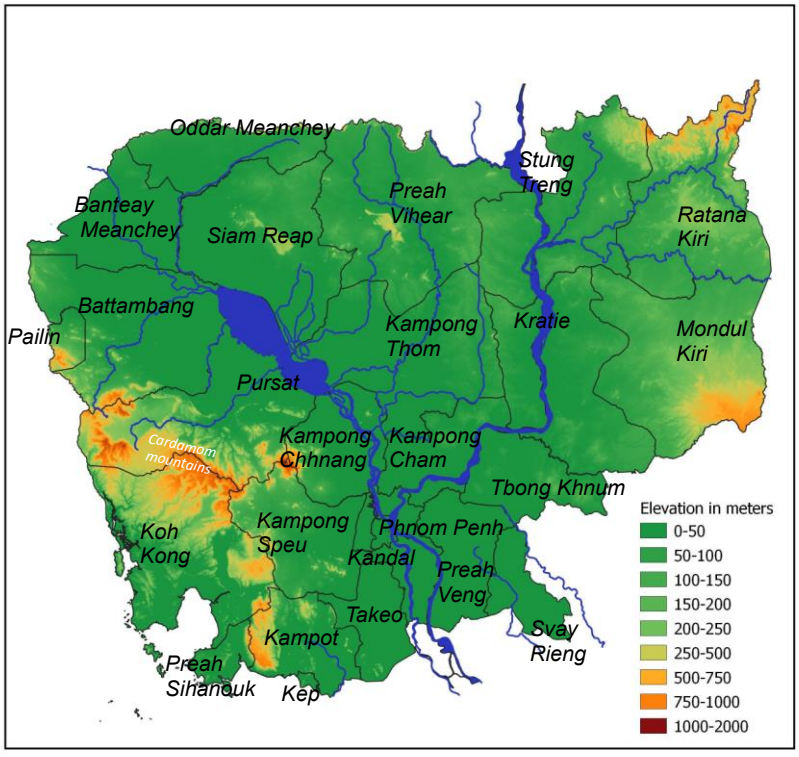


Figure 2. Topography of Cambodia

2.2 Method

As a first step, the daily data for 19 observatory locations was acquired from Department of Meteorology and processed to undertake quality checks. All observatories are not having data since 1980s, as indicated in Table-1. Month-wise average of rainfall and temperature was calculated for whatever period available[3] for each surface observatory datasets to examine the month-to-month variation/ seasonality of these two parameters for 19 locations. Further, the annual accumulated rainfall and annual mean temperature for 19 locations was plotted using GIS to examine the spatial variation of rainfall and temperature within Cambodia.

As the no. of observatories were less in Cambodia, satellite-based rainfall and temperature estimates were used to analyze the spatial and temporal variation of rainfall and temperature all over Cambodia, especially the areas that are not covered by observatories.

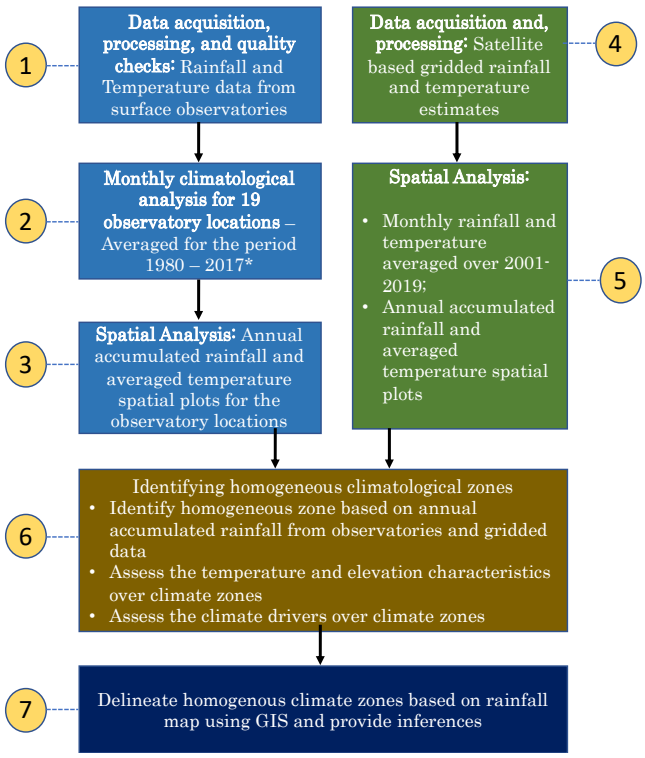


Figure 3. Methodology of identifying and delineating homogeneous climate zone

The month-wise average of rainfall IMERGM downloaded from GIOVANNI tool were plotted in a GIS platform to assess the spatial variation of rainfall across Cambodia and to compare against the observatory data. Similarly, Land Surface Temperature data estimated from MODIS satellite data were plotted to examine the spatial variation of temperature across the country. The satellite based estimates were compared with surface observatory data for validation purpose.

Spatial variability of rainfall was considered as primary parameter to identify the homogenous climate zone. Temperature does not show much variations except the elevated terrain in the south-western and north-eastern part of Cambodia. However, temperature and elevation were analysed to understand and confirm the driving mechanism of the homogeneous climate zone. Microsoft Excel, QGIS and GIOVANNI web-based tool were used to process and analyse the data and to prepare the maps.

[3] *World Meteorological Organization recommends using 30 years period (1981-2010) to derive baseline/climatology. Not all stations in Cambodia are having data for this baseline period. For this study, different time period is considered for different stations, and this can be revised when the data becomes available for the recommended baseline period in the future.*

Table 1. Summary of the data from Surface observatories

S.No	Station Name	Lon	Lat	Province	Rainfall			Temperature		
					Period	No. of years	Missing data %	Period	No. of years	Missing data %
1	Banteay Meanchey	102.97	13.59	Banteay Meanchey	1985-2017	33	0.02	1998-2016	19	0.0
2	Battambang	103.20	13.09	Battambang	1981-2017	37	0.12	2004-2016	13	0.0
3	Kampong Cham	104.67	12.25	Kampong Cham	1983-2017	35	0.38	1985-2016	32	0.0
4	Kampong Chhnang	104.52	11.46	Kampong Chhnang	1996-2017	22	0.46	-	-	-
5	Kampong Speu	104.88	12.71	Kampong Speu	1996-2017	22	0.06	-	-	-
6	Kampong Thom	104.94	11.49	Kampong Thom	1981-2017	37	0.07	2004-2016	13	-
7	Kampot	102.98	11.62	Kampot	1999-2017	19	0.04	2004-2016	13	0.0
8	Kandal	105.46	12.00	Kandal	1985-2017	33	6.14	-	-	-
9	Koh Kong	104.18	10.61	Koh Kong	1999-2017	19	0.09	2004-2016	13	0.0
10	Kratie	106.02	12.48	Kratie	1980-2017	38	5.37	2007-2016	10	0.0
11	Pailin	102.62	12.84	Pailin	2000-2017	18	5.73	2007-2016	10	0.0
12	Pochentong	104.92	11.58	Phnom Penh	1981-2017	37	3.16	1981-2016	36	0.0
13	Prey Veng	105.32	11.48	Prey Veng	1985-2017	33	0.02	2004-2016	13	0.0
14	Pursat	103.92	12.54	Pursat	1981-2017	37	1.93	1989-2016	28	0.0
15	Siem Reap	103.86	13.36	Siem Reap	1987-2017	31	0.27	1988-2016	29	3.7
16	Preah Sihanouk	103.50	10.63	Preah Sihanouk	1999-2017	19	0.03	2004-2016	13	0.0
17	Stung Treng	105.97	13.53	Stung Treng	1985-2017	33	0.01	1986-2016	31	0.0
18	Svay Rieng	105.81	11.08	Svay Rieng	1982-2017	36	0.02	2004-2016	13	0.0
19	Takeo	104.78	10.99	Takeo	2006-2017	12	0.14	-	-	-

Note: No temperature data available for Kandal, Takeo, Kampong Chhnang, Kampong Speu

3. Identification of homogeneous Climatological Zones

3.1 Inference from Surface observatories

The seasonality of rainfall and temperature was assessed from the monthly climatological plots for 19 locations (Figure-4). Rainfall data exhibits two season, wet during May to October and dry during November to April. The wet season in Cambodia is driven by monsoonal phenomena. Majority (76.6 to 88.5%) of annual rainfall is received during the wet season all over Cambodia. In general, the stations in the south-west receives heavy rainfall during the monsoon season, Koh Kong being the highest (3676 mm), and followed by Preah Sihanouk (2453 mm), and Kampot (1537 mm). The western side of high elevated terrain starting from Cardamom Mountain range in Pursat province and Koh Khong and Damrei mountain along the border of Sihanouk and Kampot province (Figure-2) were wet when compared to the stations in the eastern side of the mountain range. Stung Treng in the north-eastern region received heavy rainfall (1623 mm) next to the observatories in south-west during the monsoon season (May to October), i.e. Koh Kong and Preah Sihanouk. The north-western region receives relatively less annual rainfall as inferred from Banteay Mean Chey (1144 mm) and Pailin (1079 mm) stations, when compared to locations that receive annual rainfall up to 4201mm. The central plains received moderate rainfall (average annual rainfall 1392mm). Svey Rieng, on the south eastern side, were observed with heavy rainfall during monsoon season (1360mm), and it is peak (more than 300 mm/month) during September-October months.

Spatial variation of annual rainfall over Cambodia (Figure 5a) indicate very heavy rainfall was received over the coastal stations on the windward side of the mountain range in the southwestern part of Cambodia. Two dry patches were observed over Cambodia, northwest part of Cambodia covering Pailin, Banteay Mean Chey, and Battambang province; and south-eastern part covering Kampong Speu, Kandaal and Prey Veaeng. Stung Treng on the eastern side also received second highest to the coastal stations, and followed by two isolated patches Siem Reap and Svay Rieng stations. Figure 5b shows the spatial variation of annual mean temperature in Cambodia. The annual mean temperature over Cambodia is ranging from 27.5 to 28.6°C. Among the stations, Pailin and Koh Kong exhibits slightly lower annual mean temperature 27.5°C when compared to other parts, and this is primarily due to altitude and dense forest effect. The coastal and continental effects were clearly observed in Cambodia from monthly climatology, for instance, Preah Sihanouk in the coast were observed with the range of 27.4 - 29.3 °C and Stung Treng in the continental location were observed with 26.5 to 29.9 °C.

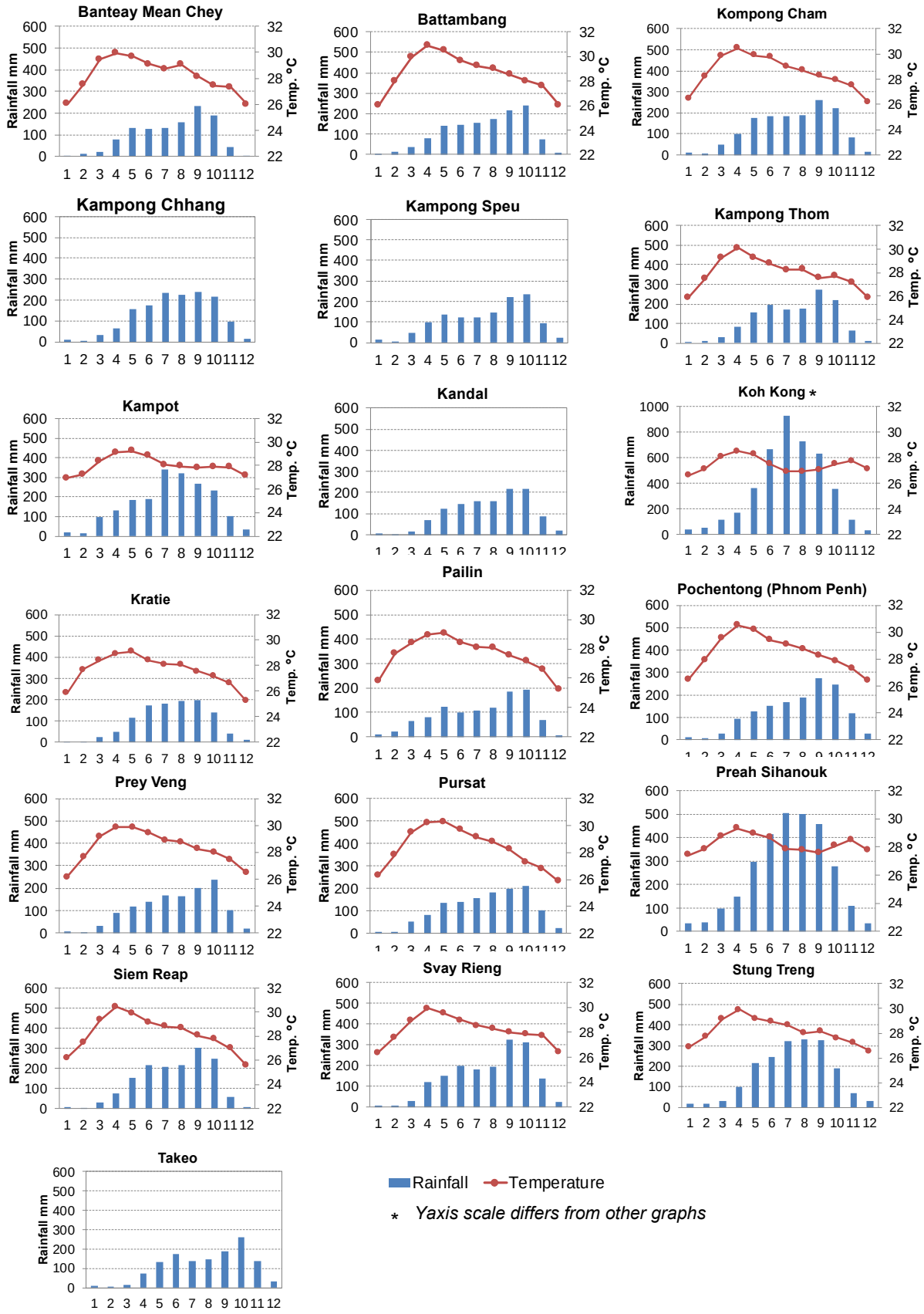


Figure 4. Monthly climatology (rainfall and temperature) of 19 surface observatories in Cambodia. (*No temperature data available for Kandal, Takeo, Kampong Chhnang, Kampong Speu*)

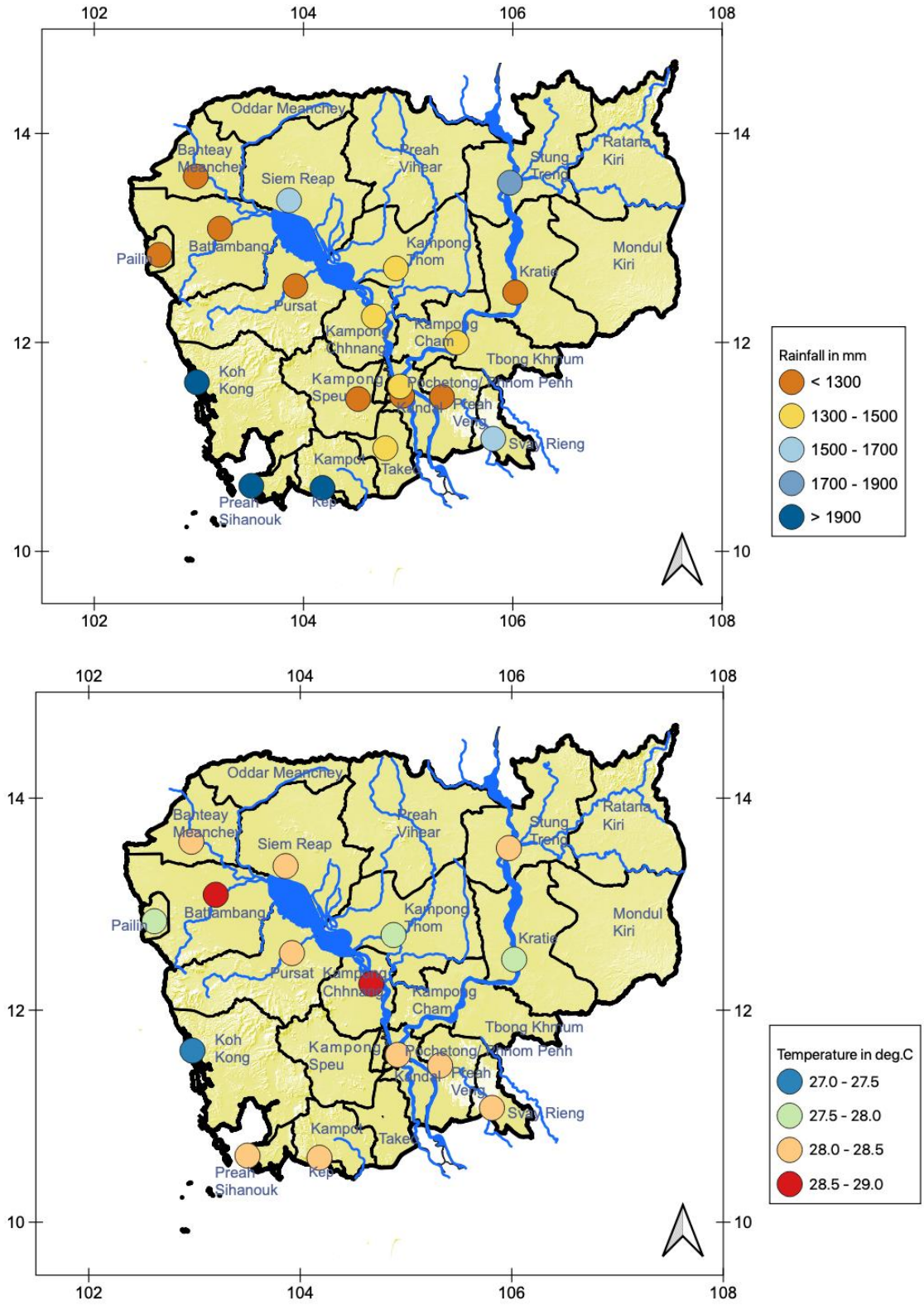


Figure 5. a) Annual accumulated rainfall in mm and b) Annual mean temperature in °C, averaged over 2001-2019. Data Source: Department of Meteorology, Cambodia

As the temperature variability across the country is not predominant, only rainfall is considered for clustering climate zones. The observatories that recorded homogeneous rainfall zones characteristics were clustered and details of climate zone is presented in Table 2 and Figure 6.

Table 2. Homogeneous Rainfall Zones in Cambodia

Zone	Stations	Rainfall characteristics	Annual Rainfall (mm)	Name of the zone
Zone 1	Koh Kong, Preah Sihanouk, Kampot	Very Heavy	1931 to 4201	South-west/Coastal
Zone 2	Pailin, Battambang, Banteay Mean Chey	Low	1079 to 1294	North-west/ Continental
Zone 3*	Siem Reap	Heavy	1520	North central/ Continental
Zone 4	Pursat, Kampong Thom, Kampong Chhang, Kampong Cham, Kratie	Moderate	1135 - 1468	Central Plains/ Continental
Zone 5	Kampong Speu, Pochentong/Phnom Penh, Kandal, Prey Veng, Takeo	Low	1261	South-central/ Continental
Zone 6	Svay Rieng	Heavy	1689	South-east/ Continental
Zone 7	Stung Treng	Heavy	1891	North-east /Continental

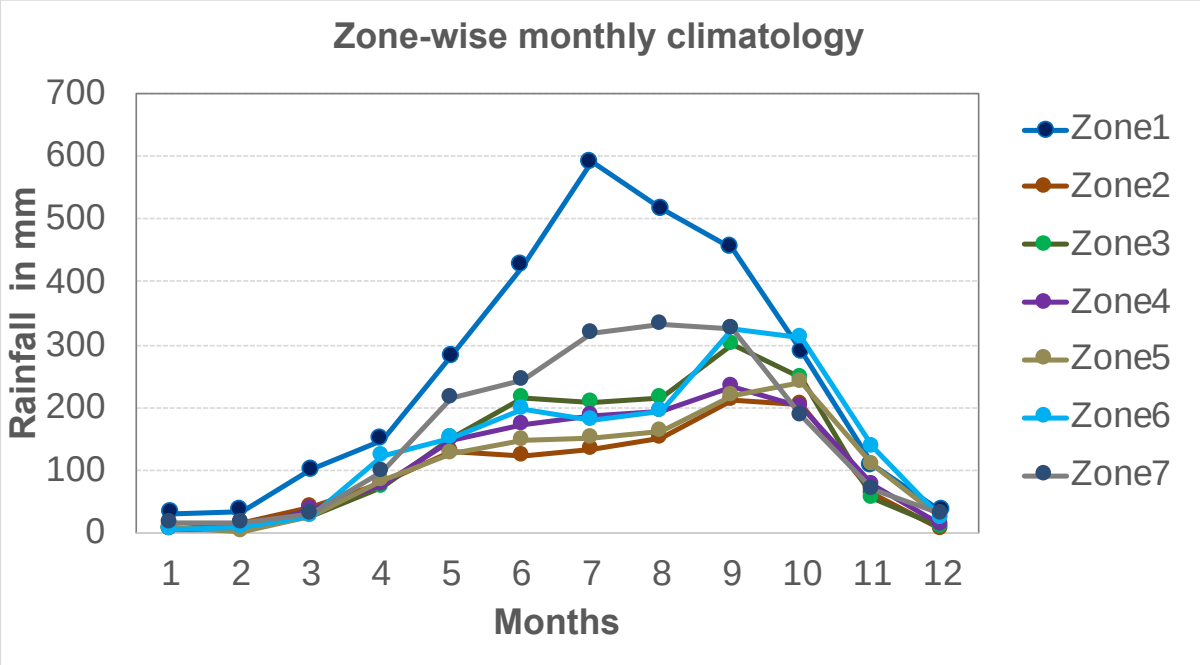
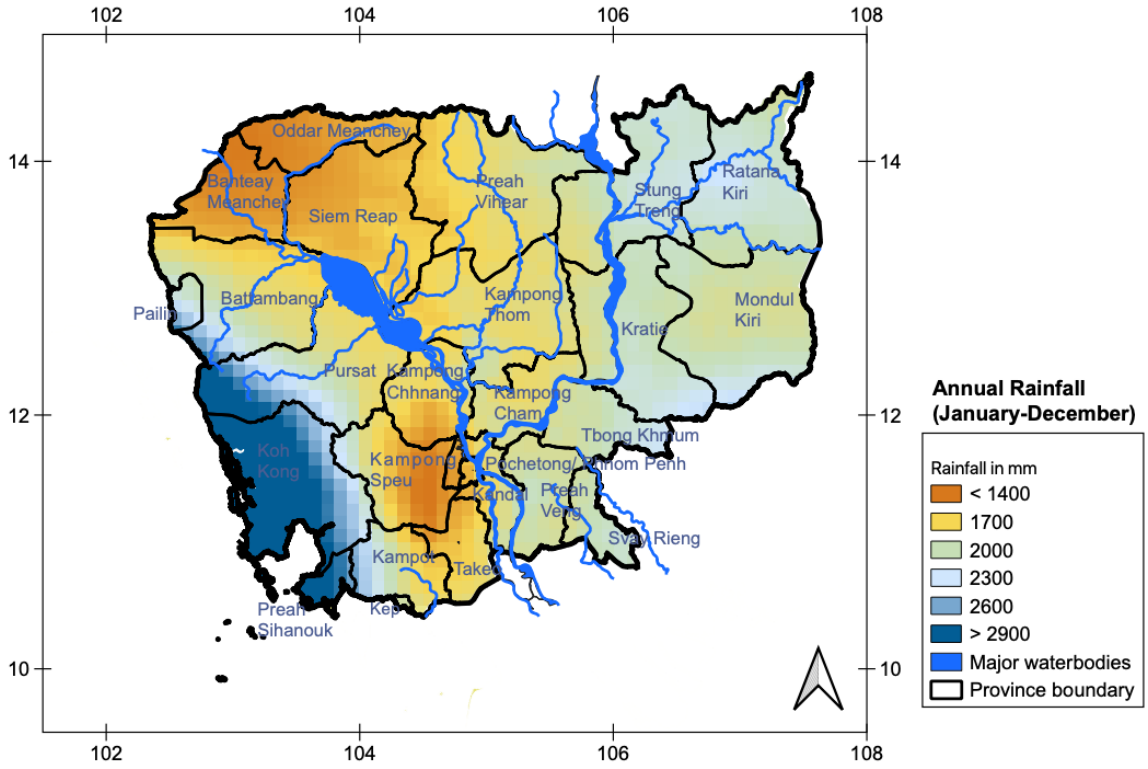


Figure 6. Zone-wise monthly rainfall climatology

3.2 Inference from Satellite based products

Comparison with Surface observatory record : The satellite-based monthly climatology of rainfall and temperature data averaged over 2000-2019 were compared with monthly climatology derived from surface observatory over the station locations[4]. The grid data of satellite based estimates within 50km radius of surface observatory was averaged for comparison. Overall, the seasonal cycle is reflected well in satellite based estimates and the correlation between satellite based estimate and surface observatories are very high. Though satellite based products relatively overestimates the rainfall quantity, but the seasonal cycle is captured well (Annex-1).

Inferences: The spatial variation of rainfall for the months January to December, May to October, November to April is shown in Figure 7, 8, and 9 respectively. The spatial pattern of rainfall observed from the surface observatory are clearly seen in satellite based estimates, i.e. wet southwest and eastern regions, and dry northwest. The west-east progression of monsoon influenced rainfall characteristics over Cambodia from May to October months were noticed, with very heavy rainfall being observed over the southwest coast during the month of July (Figure 10). During the withdrawal of monsoon i.e. during the October month, only southwestern and southeastern parts of Cambodia received rainfall (Figure 10). Except the elevated terrain, all other areas exhibit warmer temperature across Cambodia throughout the year. The temperature is much warmed during the months of March-May (Figure-11).



[4] The time period considered for these two datasets are different because of data limitations. The purpose here is to compare the monthly climatology for inference purposes.

Figure 7 Satellite based estimates of annual rainfall (January to December) over Cambodia

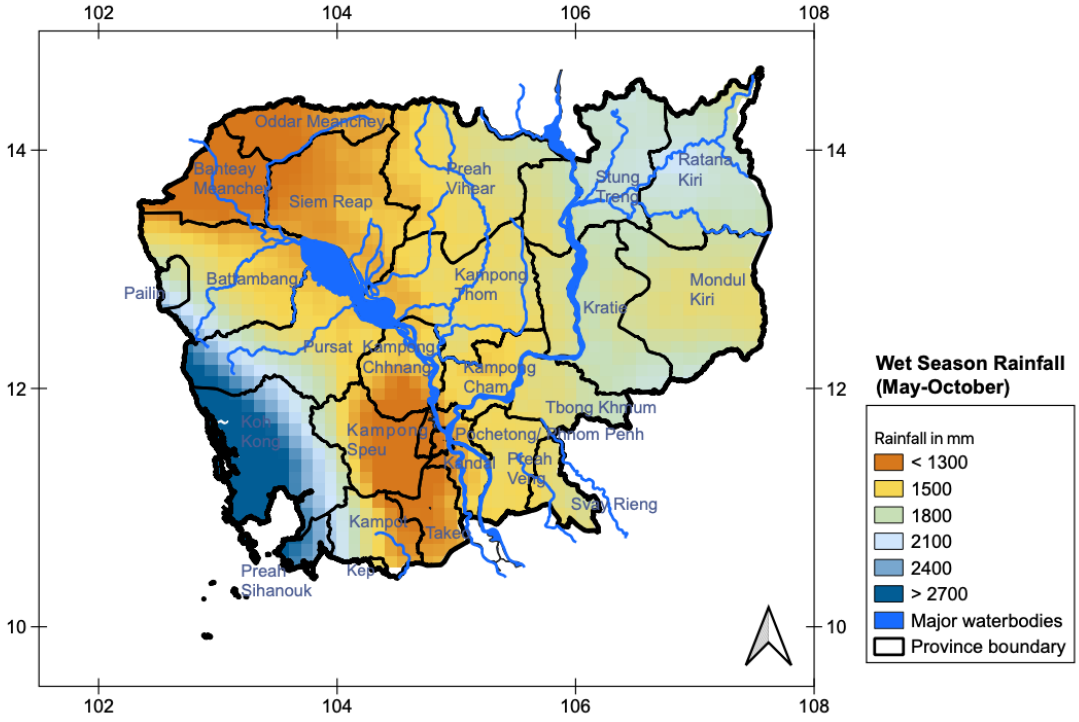


Figure 8 Satellite based estimates of wet season rainfall (May to October) over Cambodia

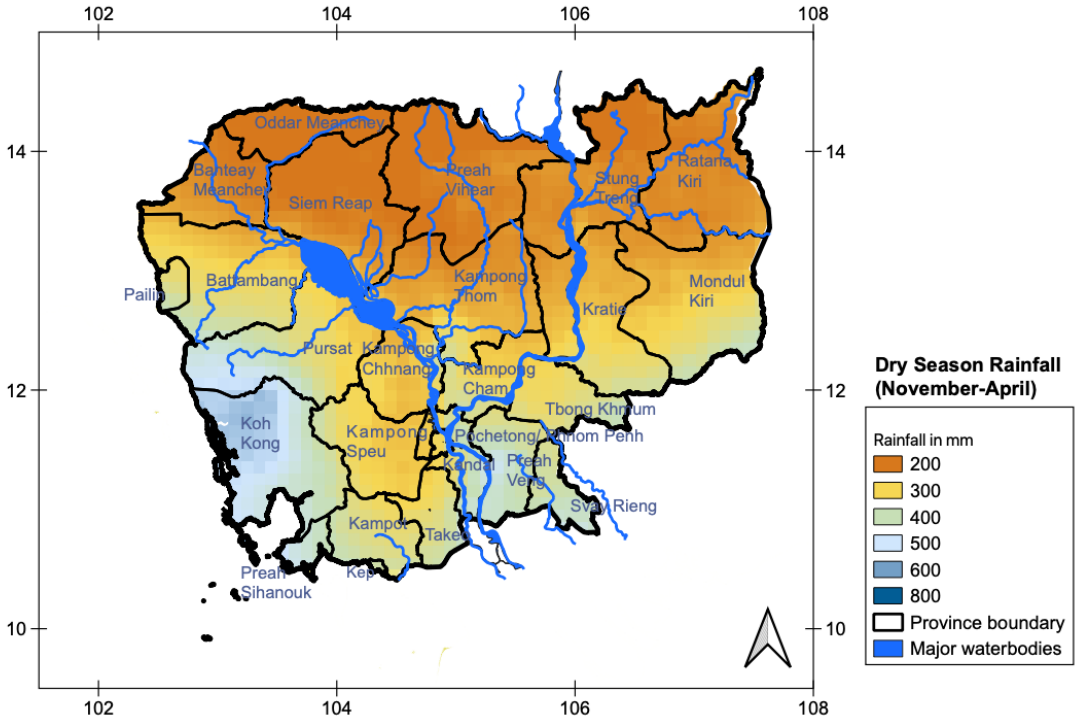


Figure 9 Satellite based estimates of dry season rainfall (November to April) over Cambodia

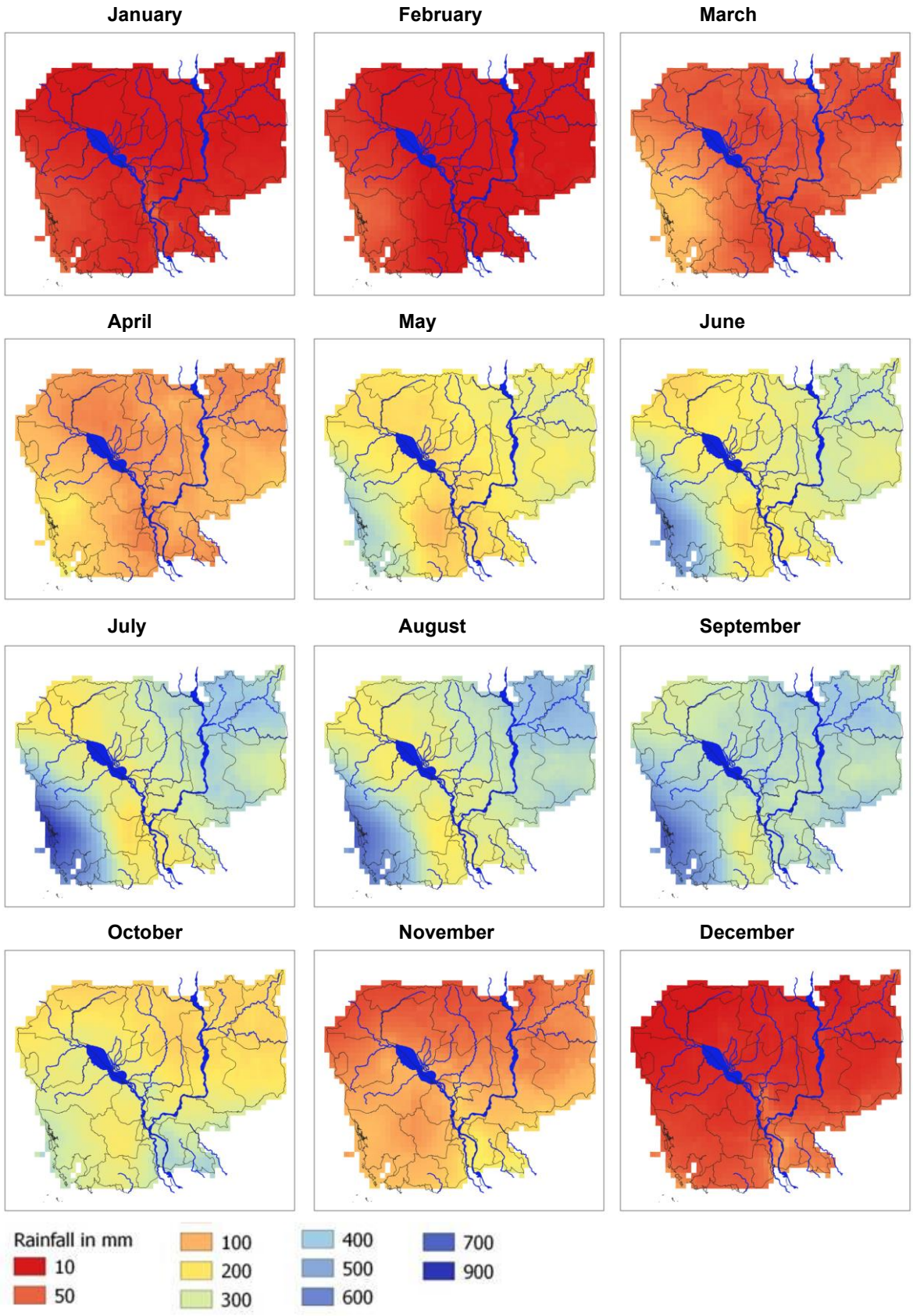

January
February
March
April
May
June
July
August
September
October
November
December
Rainfall in mm
10
50
100
200
300
400
500
600
700
900

Figure 10. Month-to-month variation of rainfall inferred from satellite based rainfall estimates. Data averaged for the period 2001-2019. Data Source: NASA

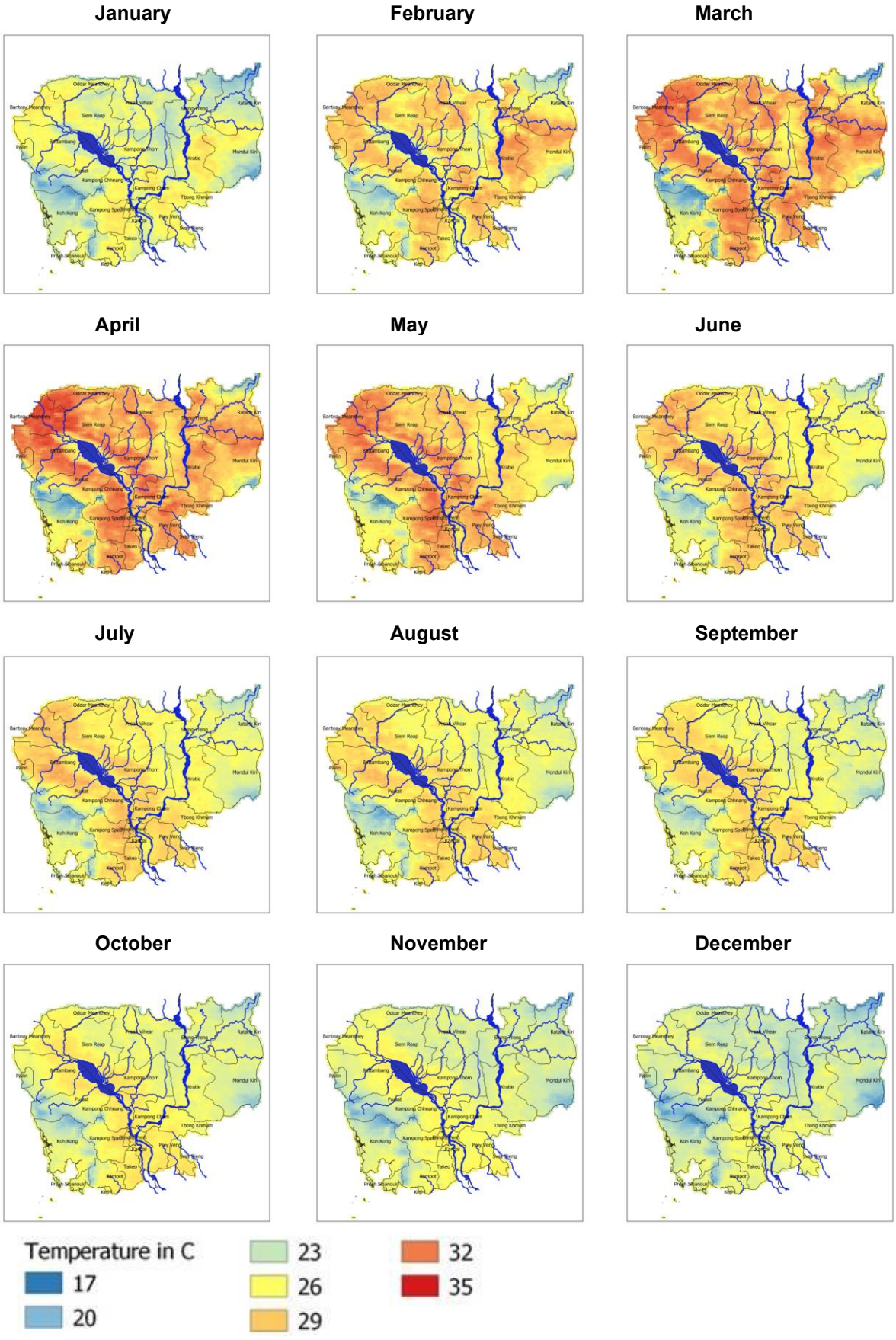


Figure 11. Month-to-month variation of temperature inferred from satellite based temperature estimates. Data averaged for the period 2001-2019. Data Source: NASA

The spatial pattern inferred from satellite-based estimates are very consistent with surface observatories and they capture the seasonal cycle well. Therefore, satellite based precipitation estimates were used to delineate the boundaries of homogeneous climate zones, though the observatory data was primary one.

3.3 Large scale climate features

The winds at 850hPa indicate the winds are westerlies/south westerlies during May to October, and north easterlies during November to April months (Figure 12). Month to month variations in wind direction and speed is shown in Figure 13. The monsoonal winds establish in the month of May, and intensifying over entire Cambodia during the month of June to August. The monsoon winds are stronger during September only in the southern part of Cambodia, and weakens during October and the reversal of wind starts in October and north easterlies well establish during the month of November and it continues until the month of April. The monsoon winds are very strong over the southwestern region, where the heavy rainfall was observed.

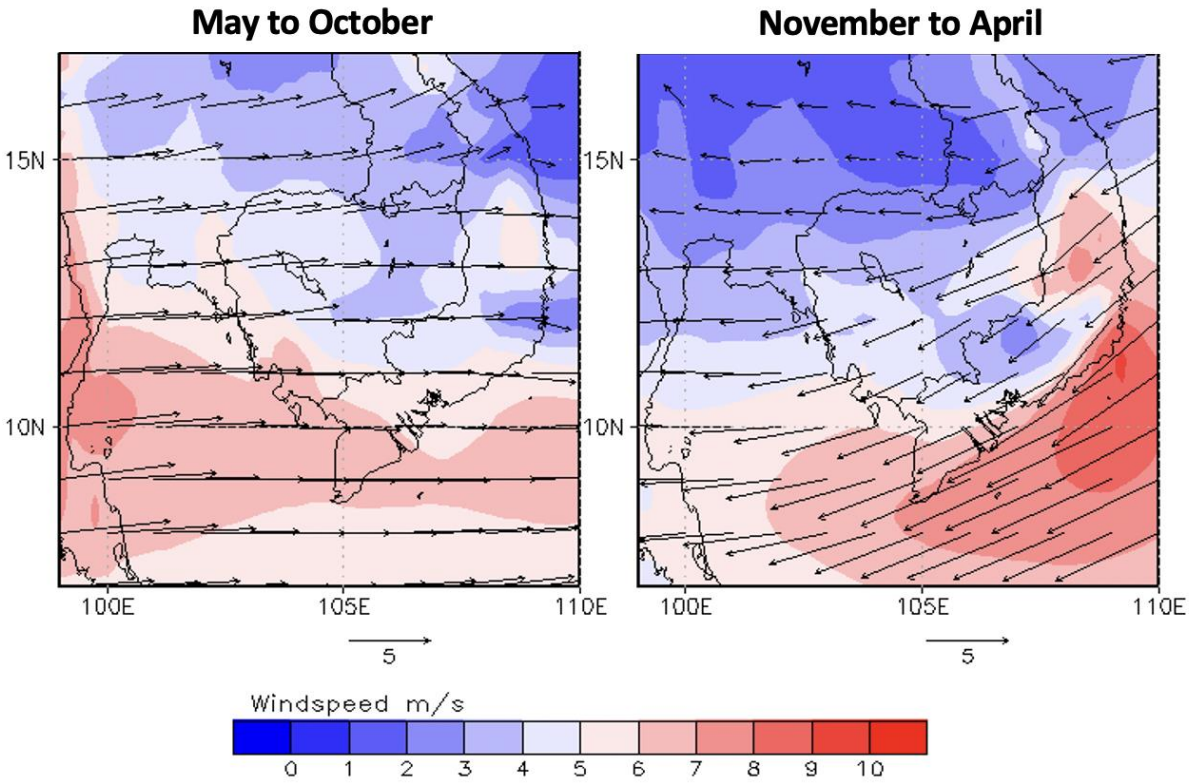


Figure 12. Winds at 850 hPa (~1.5 km above MSL) a) May – October and b) November to April

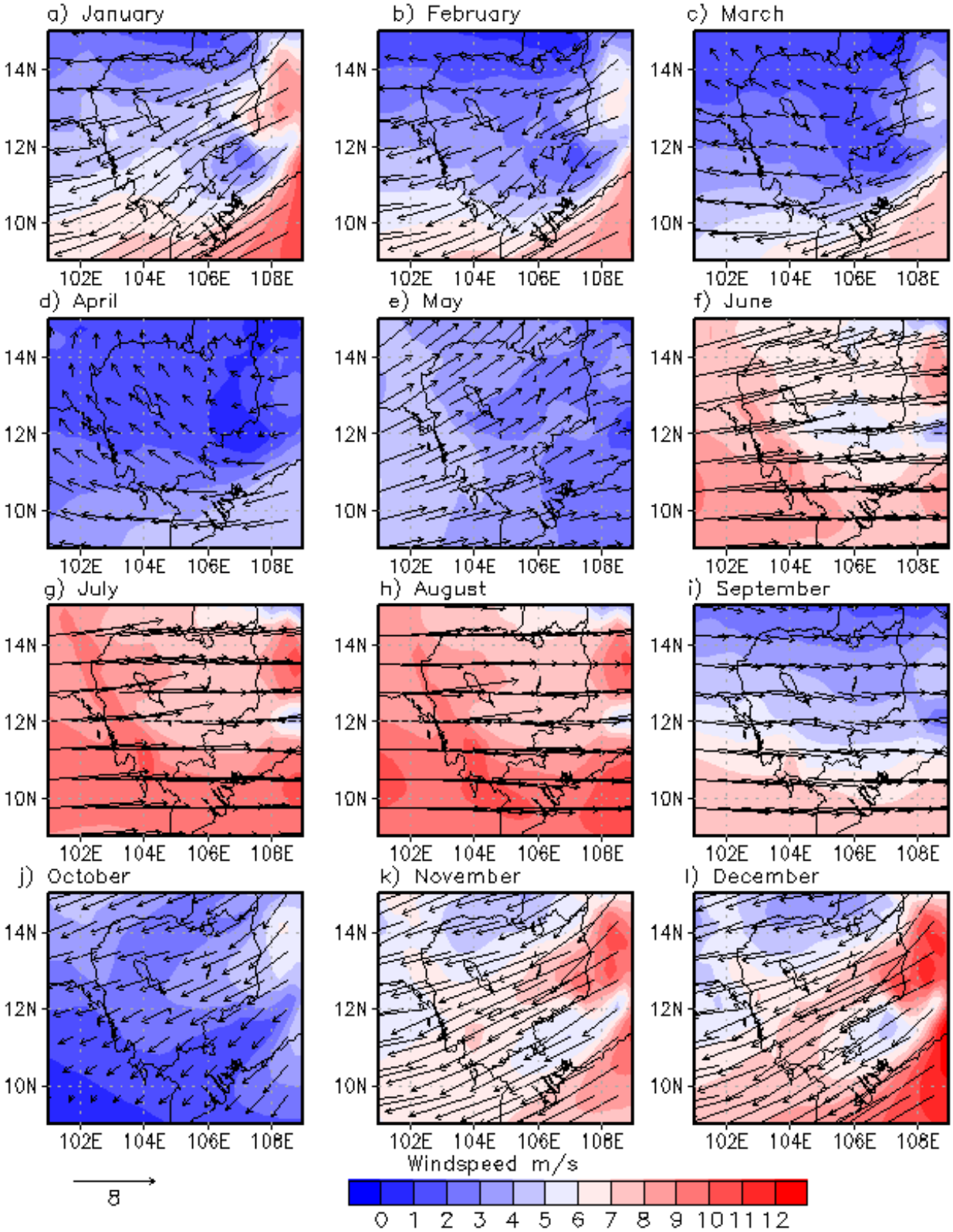


Figure 13. Monthly winds at 850 hPa (~1.5 km above MSL)

The southwestern region, i.e. the land areas on the windward side of the elevated terrain (mountain range) is one of the major physical feature act as barrier to precipitate most of the rainfall in this region and causing relatively drier over the leeward side of the mountain ranges (Figure 2). Further, there are some high elevated terrains were observed in eastern region of Cambodia, where rainfall was observed to be higher.

The dense vegetation over the southwest region (Figure 14) could act as localized climate driver in sending more moisture to atmosphere through evapo-transpiration processes.

Figure 14. Landcover map of Cambodia

4. Delineation of Climate Zones

The homogenous rainfall zones were primarily characterised using data from surface observatory. Further the satellite based estimates provided confirmation of the characterized zones, as well as provided the spatial extent of the zone to delineate the boundary. QGIS was used to digitize the zone boundaries manually (polygons) to delineate the boundary of homogeneous climate zones as shown in Figure-16. Further the ESRI Shapefile format of the digitized climate zone boundary will be integrated into RIMES developed Forecast Customization System (FOCUS) for generating climate zone wise seasonal forecast for Cambodia.

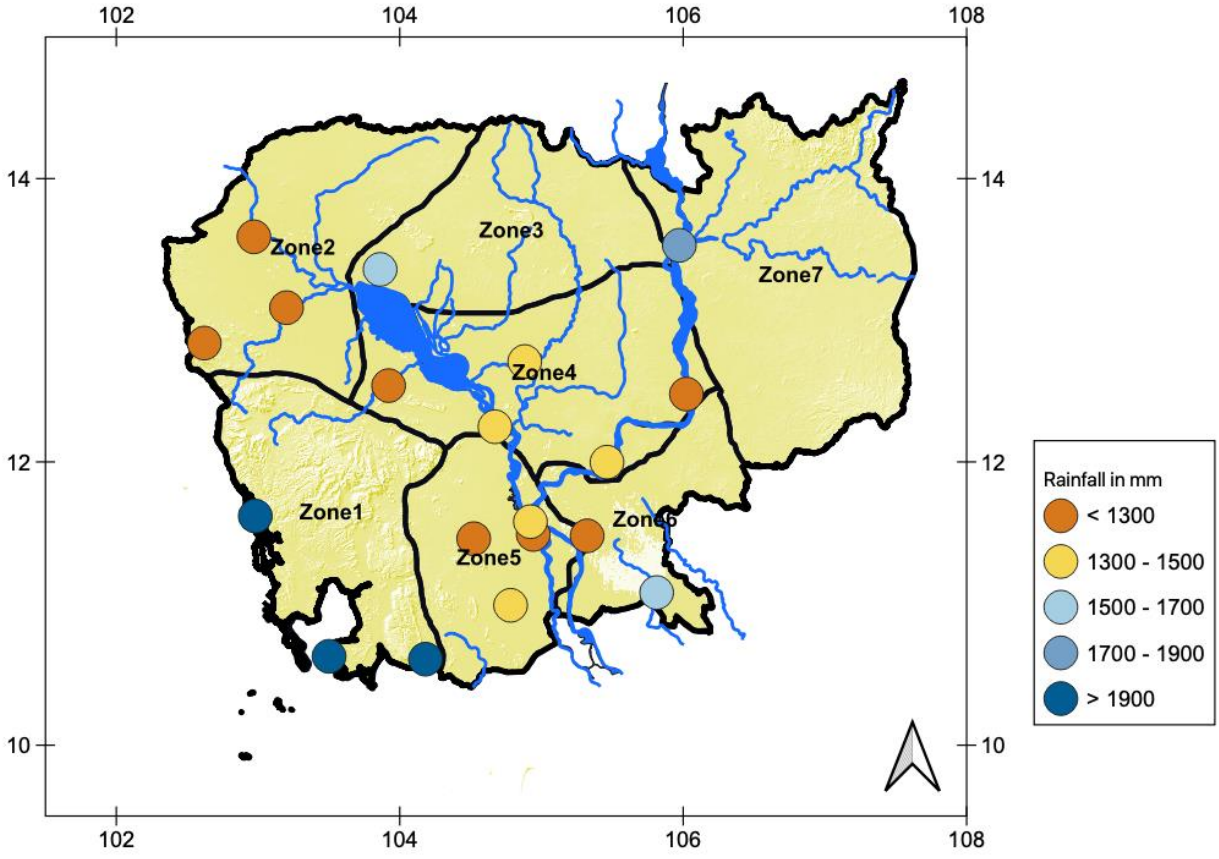


Figure 15. Climate Zone map of Cambodia

Annex -1

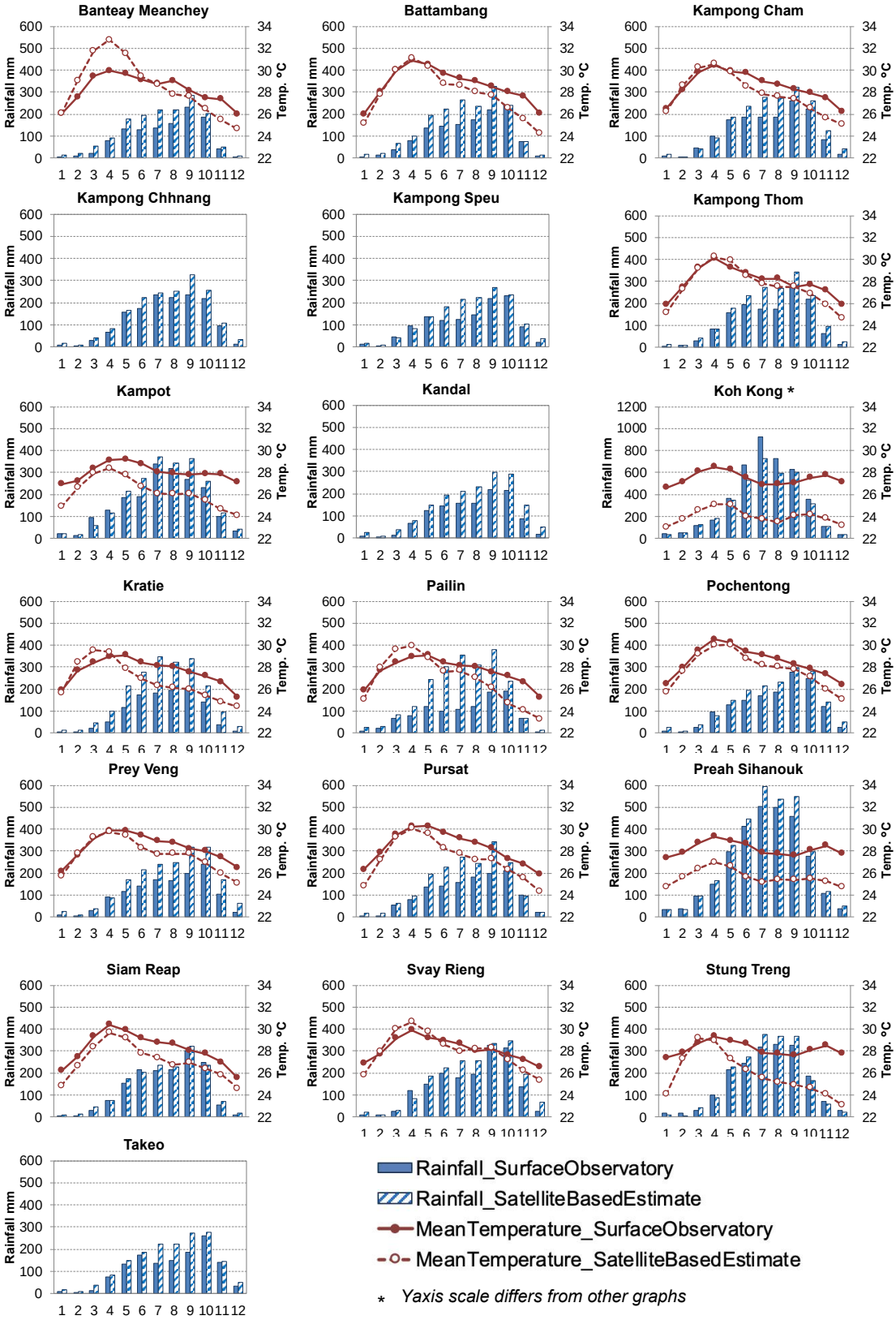


Figure A1a. Comparison of monthly climatology derived from satellite-based estimates and surface observatory records

Table A1a. Correlation between the monthly climatology from satellite-based estimates and surface observatory records

Station	Pearson correlation coefficient	
	Rainfall	Mean Temperature
Banteay Meanchey	0.977	0.884
Battambang	0.950	0.970
Kampong Cham	0.974	0.923
Kampong Chhnang	0.984	
Kampong Speu	0.935	
Kampong Thom	0.973	0.976
Kampot	0.975	0.795
Kandal	0.991	
Koh Kong	0.992	0.900
Kratie	0.992	0.767
Pailin	0.828	0.900
Pochentong	0.988	0.985
Prey Veng	0.981	0.927
Pursat	0.954	0.973
Siem Reap	0.993	0.975
Preah Sihanouk	0.997	0.872
Stung Treng	0.995	0.862
Svay Rieng	0.968	0.928
Takeo	0.953	