

# Developing Capacities for Effective Climate Services in Bhutan (Climate Services Toolkit)

2017-2018



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## Background

Activities carried out NCHM (National Centre for Hydrological and Meteorological Services, Royal Government of Bhutan) in collaboration with WMO, World Bank, Finnish Meteorological Institute, India Meteorological Department (IMD) and RIMES (Regional Integrated Multi-hazard Early-warning System) in the past three years have resulted in a good understanding of existing capacities and needs, both from NCHM's perspective and from user agencies standpoint. The SASCOF-10 conducted in July, 2017 and the National Climate Outlook Forum (NCOFs) conducted in the past three years (2015-2017) have been instrumental in raising awareness about climate services and provided a basis for implementing systems such as the CST (Climate Services Toolkit) to enable NCHM to provide effective climate services in Bhutan.

NCHM, with the support of WMO, organized a stakeholder workshop recently during 7-9 November 2017 to assess the capacities and needs of providers and users of climate services in support of decision-making by the agriculture sector in Bhutan in Thimphu, Bhutan. The stakeholder workshop convened by NCHM brought together participants from key agencies like Department of Agriculture, Department of Disaster Management, academic institutions, media and development partners (World Bank, JICA, UNDP). Technical partners such as the RIMES, involved in the Canada Government funded WMO project to implement the Global Framework for Climate Services (GFCS) in South

***One of the clear recommendations from the NCHM convened stakeholder workshop of November 2017 was to customize CST to enable NCHM to generate sector-specific climate products and services.***

Asian countries including Bhutan and the IMD, with its extensive experience in agromet services were also present at the workshop. The meeting focused on available climate information and services for agriculture at global, regional and national scales. The emphasis of the event was also to understand specific requirements of Bhutanese agricultural sector users facilitated by group discussions and consultations with individual participants.

*(Refer report of the 7-9 November 2017 Stakeholder workshop held in Bhutan in Thimphu, Bhutan)*

The core operational component of the GFCS is the CSIS (Climate Services Information System) designed for producing and operationally delivering authoritative climate information data and products at regional and national levels. Its functions include climate analysis and monitoring, assessment and attribution, prediction (monthly, seasonal, decadal) and projection (centennial scale) as well as tailoring the associated products to meet user

requirements. This is done through appropriate operational mechanisms, data exchange, technical standards, authentication, communication and product delivery. At the national level, CSIS is enabled by the Climate Services Toolkit (CST), consisting of a suite of guidance, data, software tools, training resources, and examples.

### **Objective**

This project proposal is to implement effective Climate Services in Bhutan by developing capacities at NCHM through operationalization of the CST components designed to meet user requirements primarily in the sectors of Agriculture, Water Resources, Health and Disaster Risk Reduction.

### **Implementation Strategy**

The project implementation will build on existing and on-going work of development partners, WMO, IMD and RIMES addressing the requirements articulated by users agencies in their interactions with NCHM. Work accomplished in CST aligned initiatives like the on-going WMO Data Rescue project and the NCOF process could perhaps be directly synthesized into the proposed work.

A two-tiered approach is proposed to be adopted to build capacities and enhance climate services in Bhutan –

Tier-one will be focused on strengthening the GFCS framework by sustaining the regional (South Asian Seasonal Climate Outlook Forum –SASCOF), National Climate Outlook Forum (NCOF) and subnational flow of climate information. This is expected to be supported by Regional Climate Center (RCC), Pune run by IMD and through continued support to NCOF by RIMES. RIMES will also work with NCHM and other sector level agencies like DoA to take climate information products further to Dzongkhag levels. At NCHM level this shall involve strengthening and sustenance of CST components for Climate Database Management System (CDMS) linked to both rescued data and climate data flowing in from the growing network of meteorological stations. CST components chosen to effectively use this data and translate them to climate information relevant for national and sectoral context will be identified.

Tier-two will work bottom-up and identify sector wise requirements for specific climate-linked decision points. This is expected to lead to targeted capacity development to support the operational use of climate information generated by NCHM. Design and development of decision support tools based on CST guidance for each of the key sectors (Agriculture,

Health, Water/Energy and DRR) co-developed by sector agency, NCHM, IMD and RIMES will be the main task.

The project will be implemented in two phases, Phase I (Jan 2018 -March 2018) and Phase-II (April 2018 – March 2019).

### Phase I Activities

- Review and consolidation of ongoing activities that could be incorporated into the CST Guidance framework
- Workshop and training sessions – at the national and Dzongkha level, particularly focused on agriculture sector to promote awareness on climate information – IMD’s extensive experience will be useful; IITM extended and monthly range products details can be shared
- The main aim of activities within this phase would be to devise end-to-end designs to deliver climate information products to ultimate users in each of the identified sectors viz., Agriculture, Water Resources, Health and Disaster Risk Reduction.
- Level of customization required, to deliver such products that can effectively assist decision making at the location and sector-specific levels, will be assessed. Based on this assessment – test-bed cases shall be identified by NCHM and other involved sector agencies in Bhutan. Final identification of the test-bed cases will be made for each of the four sectors based on consultative discussions of all collaborating partners.
- Design solutions shall be essentially based on the CST resources and decision-points to be identified within operational systems in the various sectors at national, Dzongkha and community levels tailored to contexts. Such systems will source information and data available from NCHM, IMD, IITM, Pune, RCCs, GPCs and other agencies to implement climate services.
- A prototype system for agriculture sector will be set-up for demonstration at the end of Phase I (April 2018).

### Phase II Activities

- Regular conduct of NCOFs at national and at identified Dzongkha levels.
- Sector-wise implementation of all the CST guided solutions, one for each of the identified sector
- Training workshops for both NCHM officers and sector level experts who will be using the systems. NCHM officials will undergo hands-on training at IMD, IITM, Pune, KMA

and RIMES while the tools are being customized. For the sector, this will be a two-stage process, one to discuss the systems and solutions being designed and the other when the tools are fully developed and being deployed for field testing.

- Phase II activities in each sector will conclude with detailed plans and approach to scaling up systems to other locations and forward-looking strategies to constantly imbibe new sources of information, data and analytics.

### Climate information needs:

Current utilization of DHMS products, and gaps in climate information utilization based on desktop reviews and consultations/meetings/focused group discussion with the stakeholder institutions during the course of the WMO GFCS project are summarized in Annex I.

### Work Plan

	Tasks	Schedule	Approach
<b>Phase I Jan-Mar., 2018</b>			
1.	Review of climate information needs of Department of Agriculture and NCHM capacity development needed to fill gaps in a priority driven manner. Identification of location and issues.	3 <sup>rd</sup> week Feb 2018	A systematic review of existing reports, ongoing work and consultation meetings with DoA, RGB
2.	Agriculture sector Dzongkhag level awareness meetings and identification of needs, availability of agricultural data	2 <sup>nd</sup> week of Mar 2018	Plan meetings/discussions in consultation with NCHM and DoA, RGB
3.	Assess data rescued under the ongoing WMO project and QC datasets available with NCHM & RIMES. Compile and share it with RCC, IMD, Pune for customized climate information products for Bhutan	3 <sup>rd</sup> week Feb to 2 <sup>nd</sup> week March 2018	In consultation with IMD, Pune, NCHM and RIMES
4.	Identify suitable CST components for implementation	March 2018	In consultation with IMD, Pune, NCHM and RIMES
5.	Design prototype system for agromet advisory services at identified Dzongkhags. (ref Annex II for a schematic of components)	end of Mar. 2018	IMD AgroMet system to be customized to include
<i>The budget for tasks 1-5 to be implemented during Jan-Mar, 2018 will be met from WMO GFCS Canada Government project funds available with RIMES for Bhutan.</i>			
<b>Phase II Apr. 2018 to Apr. 2019 [funding supported by KMA (?)]</b>			
6.	Integration of ensemble seasonal predictions, extended and sub-seasonal products from KMA Lead Centre, IITM, Pune	Apr-Sept, 2018	Through secondment training (duration to be decided by NCHM) of NCHM officers at RCC, IMD, Pune, IITM, Pune,

			KMA and RIMES – to be discussed and decided.
7.	Sector level meetings and consultations to design and implement customized CST in Health, Water and DRR sectors	Apr-May, 2018	Concerned departments of the RGB, NCHM, IMD and RIMES
8.	Data collection, development and deployment of prototype systems for Health, Water and DRR sectors; operational testing of the Agricultural sector system.	Apr-Dec, 2018	Concerned departments of the RGB, NCHM and RIMES
9.	NCOFs to be conducted at national level and Dzongkhag level	Apr and Oct. 2018	NCHM and RIMES with resource persons from IMD/IITM, Pune, KMA
10.	Mid-term meeting to discuss the design of the DSS with respective sector level agency to ensure acceptability and participation of decision-making level officials and also to build effective links with NCHM for long term work and scale-up at the national level.	Apr. to Oct 2018	NCHM, RIMES and IMD
11.	Sector level training workshops for each sector viz. Agriculture, Health, water and DRR	Jan-Mar., 2019	Concerned departments of the RGB, NCHM, IMD and RIMES
12.	Preparation of reports and hand over of systems to NCHM and concerned sectors at National and Dzongkhags levels	Mar. – Apr. 2019	NCHM, RIMES and IMD



**Summary of the climate information utilization and needs of various sectors and the gaps that limit the full utilization of available climate information and forecast products**

Institution/ Stakeholders	Climate sensitive planning and decision-making process, activities, and ongoing projects	Climate information products and services needed	DHMS products and services currently utilized	Gaps in climate information utilization and other requirements
<b>Agriculture and Food Security Sector</b>				
<b>Department of Agriculture (DOA), Ministry of Agriculture and Forest (MOAF)</b>	<ul style="list-style-type: none"> <li>○ Setting of annual and cumulative targets for cereal production as the basis of plans, activities, and project planning</li> <li>○ Development of crop calendar</li> <li>○ Agriculture extension services</li> <li>○ Irrigation</li> <li>○ Double cropping/winter cropping</li> <li>○ Research and development of high yielding varieties with adaptability to certain conditions</li> <li>○ Distribution of seeds to farmers</li> <li>○ Weather-indexed insurance</li> </ul>	<p><i>Data:</i></p> <ul style="list-style-type: none"> <li>○ Quality-checked historical climate data with good coverage of stations where missing data does not exceed 3% of the total daily dataset (particularly for the weather index-based insurance scheme)</li> <li>○ Climate and Synoptic data</li> <li>○ Climatic zone-wise agro-meteorological and hydrological data for irrigation planning and management</li> <li>○ Important parameters: rainfall amounts and intensity, wind, solar radiation, soil temperature and soil moisture</li> </ul> <p><i>Products:</i></p> <ul style="list-style-type: none"> <li>○ Localized seasonal forecast, at least at the district level</li> <li>○ Localized Weather forecasts of longer timescales (i.e. 10-14 days)</li> </ul>	<p>Historical climate information for setting of annual and cumulative targets in cereal production in FYPs</p>	<ul style="list-style-type: none"> <li>○ Lack of capacity in analyzing hydrological data</li> <li>○ Lack capacity in making climate information and forecast products relevant to the context of farmers as well as in their own activities e.g. research.</li> <li>○ Information including early warning or announcements of extreme weather are not received in a timely manner or at all</li> </ul>

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		<ul style="list-style-type: none"> <li>○ Constant monitoring of weather in defining a trigger for payment in the insurance scheme</li> <li>○ Early warning and advisory for unusual weather conditions or hazards i.e. drought, flood, pest outbreaks, hail, frost</li> <li>○ Agro-advisory bulletins with information specific to different crops in different agro-ecological zones</li> <li>○ Climate services for different agro-climatic zones</li> <li>○ Documented experts' views and assessment of climate-related risks and challenges Bhutan</li> </ul>		
<b>Farmers</b>	<ul style="list-style-type: none"> <li>○ Planning of farm activities</li> <li>○ Requesting for seeds from the government</li> <li>○ Sowing</li> <li>○ Transplanting</li> <li>○ Fertilizer application</li> <li>○ Pesticide application</li> <li>○ Harvesting</li> <li>○ Sun drying</li> </ul>	<ul style="list-style-type: none"> <li>○ Information about dry spells, wet spells, or clear days without rain, and rainfall events</li> <li>○ Localized Weather forecasts of short to longer timescales (i.e. 3 days, 10-14 days)</li> </ul>	Very few farmers use 1-day forecast, mainly for deciding whether to proceed with harvesting the following day	<ul style="list-style-type: none"> <li>○ Low level of awareness on climate information</li> <li>○ Lack access to forecasts and other climate information</li> <li>○ Credible channels for dissemination of weather and climate forecasts/information to farmers are not in place</li> </ul>
<b>Water Sector</b>				
<b>National Environment Commission (NEC)</b>	<ul style="list-style-type: none"> <li>○ Planning of water resources at the national level</li> <li>○ Formulation of water policy and required legislation</li> <li>○ International Water cooperation</li> </ul>	<ul style="list-style-type: none"> <li>○ Climatology and climate map of Bhutan reflecting the annual average rainfall and temperature of the country.</li> <li>○ Data and analysis of changes in</li> </ul>	Historical Data	<ul style="list-style-type: none"> <li>○ Focused on medium- to long-term planning so seasonal and short-term forecasts are not utilized</li> <li>○ Existing water user</li> </ul>

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	<ul style="list-style-type: none"> <li>○ Licensing and regulating activities</li> <li>○ Report to the Government/ National Assembly</li> <li>○ Collaboration with other relevant institutions on: <ul style="list-style-type: none"> <li>● Research, development planning and support</li> <li>● Capacity building and technical backstopping</li> <li>● Data collection and distribution</li> <li>● Flood and disaster management related to water resources</li> </ul> </li> </ul> <p>Activities under the Water Resource Adaptation Plan</p> <ul style="list-style-type: none"> <li>● Survey, mapping and assessment of quality and quantity of water resources</li> <li>● Analysis of glacial and seasonal snow covers</li> <li>● Hydrological modelling for vulnerability assessment of water resources to climate change</li> <li>● Construction of multi-purpose impoundments to store water during lean season</li> <li>● Rural Water Harvesting</li> </ul>	<ul style="list-style-type: none"> <li>seasonal averages and changes or trends in extreme event frequency and intensity</li> <li>○ Analysis of sediment load data to determine disturbances in the upstream watershed for the state of environment reporting</li> <li>○ Documentation of the drying up of some water sources, analysis of trends in sedimentation, and water flow volume</li> <li>○ Indicators for climate-related hazards (e.g. flashfloods) including maximum total 1-week precipitation, inventory of potential hazardous GLOF Rivers, and frequency of days with more than 100 mm rainfall per year</li> <li>○ Seasonal forecasts for activities/projects involving tapping of stream water</li> <li>○ Climate change scenarios for National Adaptation Plans</li> <li>○ Downscaled climate scenarios for medium to long term adaptation planning</li> </ul>		<ul style="list-style-type: none"> <li>institutions have weak functional linkages at policy, planning and programming levels.</li> <li>○ Needs capacity building in GIS and modelling</li> </ul>

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	<p>(RWH) for rural and urban areas</p> <ul style="list-style-type: none"> <li>• Water demand management</li> <li>• Establishment of EWS and upgrading weather forecasting centre</li> <li>• Extension of meteorological stations in the northern highlands with snow gauging</li> </ul>			
<b>Watershed Management Division (WMD), MoWHS</b>	<ul style="list-style-type: none"> <li>○ Watershed Management</li> <li>○ Integrated Water Resource Management (in collaboration with NEC)</li> </ul>	<ul style="list-style-type: none"> <li>○ Stream discharge and sediment data</li> <li>○ Rainfall data of high temporal resolution i.e. 15 minutes or shorter for understanding the impact of high intensity rainfall on Bhutan's watersheds.</li> <li>○ Depth duration frequency and analysis curves</li> <li>○ Other parameters needed: rainfall intensity, duration, magnitude, volume, evapotranspiration, runoff, sediment loss, water and sediment discharge, infiltration, water storage</li> <li>○ Local information/data on the rainfall quantity and flooding for customization of the irrigation engineering manual guide to different areas</li> <li>○ Climate Forecasts</li> </ul>	<ul style="list-style-type: none"> <li>○ Stream discharge data</li> <li>○ Stream sediment data</li> <li>○ Climate data</li> <li>○ Data on wind direction and other climate variables for categorizing watersheds</li> </ul>	<ul style="list-style-type: none"> <li>○ Weak databases used as the basis for planning models thus resulting in unrealistic and less credible results</li> <li>○ Knowledge and data gaps include extreme weather and climate and climate change, among others</li> </ul>

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<b>Community/ village leader- farmers</b>	Operation, planning, and maintenance of irrigation facilities including irrigation canals and intake facilities	<ul style="list-style-type: none"> <li>○ Information during the pre- and post-monsoon season for irrigation management during these low flow periods</li> <li>○ River flow discharge amount during the wet season, with a monthly breakdown</li> </ul>		Needs capacity building in utilizing relevant climate information and forecast products for their activities
<b>Health Sector</b>				
<b>Ministry of Health (MoH)</b>	<ul style="list-style-type: none"> <li>○ Conduct studies on the trend of risk factors in Climate-Sensitive Diseases (CSDs) (e.g. diarrheal diseases, malaria, and dengue)</li> <li>○ Analyze weather/climate-health relationship</li> <li>○ Intensified Surveillance and Response, specific activities under which include: <ul style="list-style-type: none"> <li>● Collection of environmental and climatic data in collaboration with Environmental Health and DHMS</li> <li>● Meeting with Hydromet Division, Department of Energy on climatic data collection and data sharing</li> </ul> </li> </ul> <p>Integration of climate and vector data into the web-based reporting system</p>	<p><i>Historical Data Needs</i></p> <ul style="list-style-type: none"> <li>○ Historical data of daily, weekly, monthly and annual timescale</li> <li>○ Data parameters: <ul style="list-style-type: none"> <li>● Relative Humidity</li> <li>● Wind speed and direction</li> <li>● Rainfall</li> <li>● Solar Radiation</li> <li>● Air Quality</li> <li>● Water Quality</li> <li>● Water Discharge</li> </ul> </li> </ul> <p><i>Products:</i></p> <ul style="list-style-type: none"> <li>○ Weather information on temperature and precipitation of real-time, daily, and weekly timescales</li> <li>○ Seasonal forecast with information on temperature and precipitation and unusual rainfall pattern especially around the end of monsoon season</li> </ul>	<p>Historical Data:</p> <ul style="list-style-type: none"> <li>○ Monthly/Annual Average temperature</li> <li>○ Monthly/annual average rainfall</li> <li>○ Relative humidity</li> </ul>	<ul style="list-style-type: none"> <li>○ Limited surveillance data</li> <li>○ Representativeness of weather data and quality</li> <li>○ Methods and tools for analyzing climate and health data</li> <li>○ Lack of proper mechanism for collaboration and information delivery</li> <li>○ Weak collaboration and interaction between DPH and DHMS</li> <li>○ Low capacity in understanding and translating climate information, impact forecasting, and decision support systems in the health sector</li> </ul>

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		<ul style="list-style-type: none"> <li>○ Climate summaries or climate/seasonal trends</li> <li>○ Climate projections</li> <li>○ Risk Mapping</li> <li>○ Early warning for natural hazards including events of extremely low temperature</li> </ul>		
<b>Disaster Risk Reduction/Management Sector</b>				
<b>Disaster Management Committees (Dzongkhag, Thromdes, Gewog)</b>	<ul style="list-style-type: none"> <li>○ Prepare, review, update and implement Disaster Risk Management and Contingency Plan</li> <li>○ Promote education, awareness, capacity building, and community training, with the support of DDM, on hazard, risk, vulnerability and measures to be taken by the community to prevent, mitigate and respond to disaster</li> <li>○ Conduct a regular mock drill</li> <li>○ Implement cross-sectoral risk reduction initiatives and build capacities to respond to disasters in their respective jurisdiction;</li> <li>○ Monitor and evaluate measures taken for prevention, mitigation, preparedness, response and capacity building by each sector in their respective jurisdiction</li> </ul>	<ul style="list-style-type: none"> <li>○ Probability of occurrence and intensity of various hazards in their area of jurisdiction for hazard, vulnerability, and risk profiling/assessment</li> <li>○ Early warning for dissemination and for activating the jurisdiction's emergency operation center</li> </ul>	None	

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	<ul style="list-style-type: none"> <li>○ Ensure compliance with approved hazard zonation and vulnerability mapping</li> <li>○ Maintain continuous contact with NEOC and disseminate information to the Dungkhangs, Gewogs, and/or Thromdes under its jurisdiction, in case of an emergency</li> <li>○ Ensure that information about an event or disaster is promptly communicated to the NDMA, DDM, and all concerned</li> <li>○ Assess the requirements, mobilize/summon resources and manpower to respond to a disaster and extend all assistance the Dzongkhag, Gewogs, and Thromdes within its jurisdiction</li> </ul>			
<b>Department of Disaster Management (DDM)</b>	<ul style="list-style-type: none"> <li>○ Develop, review, and update the Disaster Management Strategic Policy Framework</li> <li>○ Formulate National Standards, guidelines, and standard operating procedures</li> <li>○ Develop and implement the national DM and Contingency plan</li> <li>○ Facilitate the formulation of hazard zonation and</li> </ul>	<ul style="list-style-type: none"> <li>○ Multi-hazard risk information including past disasters</li> <li>○ Multi-hazard zonation and vulnerability maps/ information etc.</li> <li>○ More comprehensive records of extreme events should also be made available for defining threshold values for different hazards</li> <li>○ Short to long term weather forecast information (at least 5-10 days)</li> <li>○ 5-6 days forecast heavy windstorm</li> </ul>	<ul style="list-style-type: none"> <li>○ Announcement/ advance information on extreme events such as cyclones, windstorms, and floods</li> </ul>	<ul style="list-style-type: none"> <li>○ Current forecast products are mainly based on global climate information, whereby information on localised events are not readily available</li> <li>○ Forecasts only include temperature and rain and lack the storm/ cyclone/ windstorm event information</li> <li>○ The currently available 24-</li> </ul>

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	<p>vulnerability map</p> <ul style="list-style-type: none"> <li>○ Coordinate and support DDMCs during all phases and facets of disaster management</li> <li>○ Facilitate and ensure the development and implementation of sectoral Disaster Management and Contingency Plan and disaster management activities</li> <li>○ Risk assessment</li> <li>○ Training on awareness and advocacy</li> <li>○ DM planning and mainstreaming</li> <li>○ Training on translating disaster management related information and maps</li> <li>○ Issuance of advisory, watch message, and/or warning to signal a threatening disaster situation based on DHMS warnings/announcements of severe weather conditions</li> </ul>	<p>and cyclone events and other hydrometeorological hazards</p> <ul style="list-style-type: none"> <li>○ Forecast for thunderstorms and severe weather (heavy rains)</li> <li>○ Location-specific storm/ cyclone/ windstorm warning specifying gust and mean wind speed</li> <li>○ Wind advisory</li> <li>○ Flood advisory</li> <li>○ Flood forecast</li> <li>○ Flash flood forecast</li> <li>○ Fire weather outlook</li> <li>○ Red flag forecast</li> <li>○ GLOF early warning</li> <li>○ Cyclone forecasts</li> <li>○ Landslide warning</li> <li>○ Seasonal forecast</li> <li>○ Climate change-related disaster scenarios</li> </ul>		<p>hour weather forecast does not provide sufficient lead-time for responding to hazardous weather events.</p> <ul style="list-style-type: none"> <li>○ Lack of coordination and sharing, particularly of daily climate information, with relevant sectors; there is no common platform where information, particularly of threatening situations, can be immediately shared between DMM and responsible agencies</li> <li>○ Lack of capacity to analyze information received from responsible agencies.</li> <li>○ Improper channel of information dissemination from DDM to vulnerable communities, particularly to farmers during harvesting seasons.</li> <li>○ Climate information currently provided to the public is mostly general, does not include any graphical climate information, and thus, not useful in raising public awareness on climate variability and change.</li> </ul>



Institution/ Stakeholders	Climate sensitive planning and decision-making process, activities, and ongoing projects	Climate information products and services needed	DHMS products and services currently utilized	Gaps in climate information utilization and other requirements
				<ul style="list-style-type: none"> <li>○ Warnings are currently disseminated only through the televisions, thereby reaching a limited proportion of the population and may not reach people or areas that could be directly affected by the impending event.</li> </ul>
<b>Flood Engineering and Management Division (FEMD), Department of Engineering Service (DES), MoWHS</b>	<ul style="list-style-type: none"> <li>○ Flood hazard assessment of flood prone rivers.</li> <li>○ Preparation of flood hazard map</li> <li>○ Design and construction of appropriate flood protection structures</li> <li>○ Design and planning of urban drainage system</li> <li>○ Design and implementation of non-structural flood prevention measures e.g. floodplain zoning, land use planning</li> <li>○ Reclamation of land from flood plain</li> </ul>	<ul style="list-style-type: none"> <li>○ Hydrological data for water supply, sanitation, and flood management</li> <li>○ Flood frequency and analysis of return periods for designing flood walls</li> <li>○ Systematic rainfall and surface water data to improve the design and management of Bhutan’s road system</li> <li>○ Hourly rainfall data</li> <li>○ Discharge and rainfall data for conducting studies on cost-efficient flood protection</li> <li>○ Hydrological and hydraulic data required for the design of bridges and highways</li> <li>○ Historical hydrometeorological data for hazard mapping of human settlements and cultural heritage</li> <li>○ Climate Forecast</li> </ul>	Rainfall data and hydrological data including discharge and water	<ul style="list-style-type: none"> <li>○ Lack of reliable long term data</li> <li>○ Lack of meteorological stations</li> </ul>

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<b>Department of Human Settlement, MoWHS</b>	<ul style="list-style-type: none"> <li>○ Flood analysis and feasibility studies related to settlement planning</li> </ul>	<p><i>Data:</i></p> <ul style="list-style-type: none"> <li>○ Rainfall data and information on GLOF, flashfloods and other high-risk areas for the preparation of settlement development plans</li> <li>○ Required parameters include rainfall, temperature, wind speed and direction, discharge, water level and other relevant parameters for planning sustainable energy efficient settlements</li> </ul> <p><i>Products:</i></p> <ul style="list-style-type: none"> <li>○ Quantitative Precipitation Forecast</li> <li>○ Winter Storm Forecast</li> <li>○ Travel Advisory</li> <li>○ Travel Warning</li> <li>○ Temperature Forecast</li> <li>○ Wind Forecast</li> <li>○ Depth duration frequency</li> <li>○ Probable maximum flood</li> <li>○ Probable maximum precipitation</li> </ul>	Currently not using DHMS data and products	
<b>Department of Geology and Mines (DGM)</b>	<ul style="list-style-type: none"> <li>○ Monitor geohazards such as landslides</li> <li>○ Preparation of landslide hazard map</li> <li>○ Monitors glacial lakes</li> <li>○ Takes remedial measures for GLOF risk reduction, mainly from the geological and geomorphology perspective</li> </ul>	<p><i>Data</i> (collected at short intervals e.g. every 5 minutes or based on the event)</p> <ul style="list-style-type: none"> <li>○ Rainfall totals</li> <li>○ Rainfall intensity</li> <li>○ Rainfall duration</li> <li>○ Rainfall data collected at sub-network stations adjacent to landslide areas (for the design of</li> </ul>	Currently not using DHMS data and products	

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		structural mitigation measures)  Products and Services: <ul style="list-style-type: none"> <li>○ Depth duration frequency, depth duration curves</li> <li>○ Climate reports and special analysis of rainfall data to better determine rainfall characteristics at various landslide areas</li> <li>○ Other studies of rainfall over a smaller area</li> </ul>		

**Energy**

<b>Department of Renewable Energy (DRE)</b>	<ul style="list-style-type: none"> <li>○ Renewable Energy Resource Mapping (Solar, Wind, Small Hydropower and Biomass)</li> <li>○ Preparation of Renewable Energy Development Master Plan</li> <li>○ Preparation of feasibility study reports (Solar, Small Hydropower)</li> <li>○ Prediction of electricity consumption</li> <li>○ Identification of locations suitable for wind turbines</li> <li>○ Assessment of solar power potential</li> <li>○ Estimation of solar power generation potential and benefits</li> </ul>	<i>Data</i> <ul style="list-style-type: none"> <li>○ Discharge, hourly runoff and water level data</li> <li>○ Storm rainfall data</li> <li>○ Short interval catchment rainfall and runoff data for flood events</li> <li>○ Evapotranspiration, sediment and glacier data</li> <li>○ Atmospheric data of sufficient length (air temperature, wind direction and velocity, evaporation, etc.)</li> <li>○ Other important data parameters:               <ul style="list-style-type: none"> <li>● Temperature</li> <li>● Relative humidity</li> <li>● Wind speed</li> <li>● Wind direction</li> </ul> </li> </ul>	Historical hydrological data for various basins, where available	<ul style="list-style-type: none"> <li>○ Absence or lack of hydrological data in some river basins</li> <li>○ Hydrometric network does not cover smaller E-W catchments well</li> <li>○ Secondary stations (float method) are of poor to medium reliability</li> <li>○ No data of flood peaks at night (unless the station has Automatic Water Level Recorder or AWLR)</li> <li>○ Difficulty in obtaining accurate estimates of peak flows and very low flows</li> </ul> With only short duration data available, it is difficult to
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Institution/ Stakeholders	Climate sensitive planning and decision-making process, activities, and ongoing projects	Climate information products and services needed	DHMS products and services currently utilized	Gaps in climate information utilization and other requirements
		<ul style="list-style-type: none"> <li>• Solar radiation</li> </ul> <i>Products:</i> <ul style="list-style-type: none"> <li>○ Climate summaries</li> <li>○ Wind rose</li> <li>○ Flood analysis (for dam design)</li> <li>○ Short-term flood forecast for addressing sedimentation problems</li> <li>○ Short-term forecast of rainfall/inflow to determine peaking capacity</li> </ul>		predict natural variability of flow and extremes
<b>Bhutan Power Corporation (BPC)</b>	<ul style="list-style-type: none"> <li>○ Design and selection of sites for lines and poles</li> <li>○ Preparing for expected repairs, informing customers of possible blackouts, and estimation of possible overload situations during extreme cold spells or heat waves, among others.</li> <li>○ Demand prediction</li> </ul>	<ul style="list-style-type: none"> <li>○ Historical data for wind zone factor for better or optimized design and selection of sites for lines and poles</li> <li>○ Short- and medium-range weather forecasts</li> <li>○ Early warning containing information on the intensity of snow and storms would be helpful in improving</li> <li>○ Lightning forecast</li> <li>○ Seasonal forecasts for demand prediction</li> </ul>	Available historical information on wind zone factor	
<b>Druk Green Power Corporation (DGPC)</b>	<ul style="list-style-type: none"> <li>○ Planning</li> <li>○ Operation and Maintenance</li> </ul>	<ul style="list-style-type: none"> <li>○ Historical hydrometeorological data for planning</li> <li>○ Updated information on the station coordinates, elevation, etc.</li> <li>○ Rainfall maps</li> <li>○ Accurate real-time observations and hydrometeorological forecasts</li> </ul>	Currently not using DHMS data and products	<ul style="list-style-type: none"> <li>○ There is no assurance that the available data is sufficiently quality-checked.</li> <li>○ Available data does not sufficiently represent the areas/locations of specific interest to DGPC</li> </ul>

Institution/ Stakeholders	Climate sensitive planning and decision-making process, activities, and ongoing projects	Climate information products and services needed	DHMS products and services currently utilized	Gaps in climate information utilization and other requirements
		<p>for improving the performance and in short-term revenue forecasting for hydropower plants Green Power</p> <ul style="list-style-type: none"> <li>○ Forecasts and information on the volume of river flow during the pre- and post-monsoon period</li> <li>○ Early warning for extreme events, especially floods and cyclone</li> </ul>		<ul style="list-style-type: none"> <li>○ Information on catchment area, station coordinates, etc. is not updated.</li> <li>○ Some project catchments, particularly in E-W rivers, are unmonitored or ungauged</li> <li>○ Rainfall data is inadequate for rainfall-runoff modelling to fill gaps and for extending flow series</li> <li>○ Satellite rainfall data is too coarse to demonstrate the complexities of the distribution of rainfall in mountains</li> <li>○ Lack of instantaneous water level and rainfall data is a constraint for analysis of events less than the 1-day duration</li> </ul>

Institution/ Stakeholders	Climate sensitive planning and decision-making process, activities, and ongoing projects	Climate information products and services needed	DHMS products and services currently utilized	Gaps in climate information utilization and other requirements
<b>Department of Hydropower and Power Systems (DHPS)</b>	<ul style="list-style-type: none"> <li>○ Govern and facilitate integrated, regionally balanced and optimal use of water resources for the development of hydropower with minimal environmental impacts</li> <li>○ Ensure that hydropower exports generate maximum revenue for the Nation.</li> <li>○ Ensure secure, reliable and affordable energy for the domestic consumers.</li> </ul>	<p><i>Data:</i></p> <ul style="list-style-type: none"> <li>○ Real-time and accurate hydrometeorological data including rainfall, river discharge, suspended sediment</li> <li>○ Wind speed and wind direction data</li> <li>○ Climate data for the development/design of hydropower schemes</li> <li>○ Data that well represents the whole country particularly the higher elevations</li> </ul> <p><i>Products:</i></p> <ul style="list-style-type: none"> <li>○ Quantitative precipitation forecast</li> <li>○ Runoff forecast</li> <li>○ Temperature forecast</li> <li>○ Flood forecast</li> <li>○ Wind forecast</li> <li>○ Probable maximum precipitation (PMP)</li> <li>○ Probable maximum flood (PMF)</li> <li>○ Flood depth duration frequency, and depth duration curve</li> <li>○ Thorough data quality assurance and control</li> </ul>	<p>Historical data for design studies and operation of hydropower generation scheme.</p>	<ul style="list-style-type: none"> <li>○ Incomplete data i.e. daily observations of rainfall were not recorded on some weekends or when the observer is not available</li> <li>○ Data quality is not reliable</li> </ul>

*Schematic showing components of the Agromet decision support system*

