**Bhutan Water Resources II**

*Comparing Phenology, Precipitation, and Temperature Data in Bhutan to Assist the Himalayan Environmental Rhythm Observation and Evaluation System (HEROES) Project*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

The focus of this project was to combine vegetation phenology-derived satellite data and meteorological data and to analyze trends in vegetation phenology and climate parameters for all of Bhutan over the past 40 years (1981 – 2020). The goal of this project is to assist the Ugyen Wangchuk Institute for Conservation and Environmental Research (UWICER) to help with the efforts of the Himalayan Environmental Rhythm Observation and Evaluation System (HEROES) project, a school and community-based citizen science initiative to monitor climate change in the Himalayan mountain ecosystem. This research will also help raise climate variability awareness and expand on educational outreach.

***Abstract:***

Bhutan is vulnerable to changing climatic trends and these trends have an impact on phenological patterns. Changes in these patterns have raised concerns from local farmers of altered growing seasons. The team assessed trends in vegetation phenology throughout Bhutan from 1981-2014 by combining vegetation phenology-derived data and meteorological data. The project used VIP Phen preprocessed Advanced Very High-Resolution Radiometer (AVHRR), Normalized Difference Vegetation Index (NDVI) and Terra & Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) phenology products to derive annual trends in phenology. We also used Climate Hazards Center Infrared Precipitation with Station (CHIRPS) precipitation data and Famine Early Warning System Network Land Data Assimilation System (FLDAS) temperature data to access climate trends in the country. The team did a statistical analysis of the phenology variables: the start of season, day of peak, and length of season. Overall trendlines for all the variables were increasing which suggested that season 1(spring) is delayed, day of peak was also delayed and season 1 has gotten longer by 23.5 days. The team did a statistical analysis of temperature and precipitation data and the trend suggested that the temperature in the country was becoming warmer and receiving more precipitation. R values were calculated for satellite precipitation and temperature data compared to ground precipitation and temperature data. A high correlation between the satellite and ground data for both precipitation (R=0.85) and temperature (R=0.9) were observed. These analyses were done to assist our partners raise awareness for changes to climate in Bhutan.

***Key Terms:***

remote sensing, vegetation phenology, start of season, length of season, day of peak, AVHRR, FLDAS, CHIRPS,

***National Application Area Addressed:*** Water Resources

***Study Location:*** Bhutan

***Study Period:*** 1981 – 2020 (May – September)

***Community Concerns:***

* Bhutan is located on the fragile Eastern Himalayan ecoregion where climate change poses a threat to the environment, sustainable development, and livelihoods of the people.
* Bhutan has experienced increased warming, and this has resulted in severe change to its local climate with the decrease in the annual rainfall and snowfall over the past decade.
* Bhutan also faces high risk from glacial lake outburst floods.
* Bhutan is a non-industrialized country; it is more agriculture-based and many communities within the country are still actively involved in the field of farming, so they depend heavily on agricultural work for living and to conserve the environment.

***Project Objectives:***

* Assess trends in vegetation phenology for start of season, day of peak, and end of season 1 from 1981 to 2014
* Analyze precipitation and temperature trends from 1981-2020 for whole country

***Previous Terms:***

2020 Summer (MSFC) – Bhutan Water Resources

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ugyen Wangchuck Institute for Conservation and Environmental Research (Bhutan)** | Changa Tshering, Head of Information Services | End User | No |
| **Karuna Foundation** | Lindsay Skog, Program Director | Collaborator | No |
| **Bhutan Foundation** | Tshewang Wangchuk, Executive Director | Collaborator | Yes |

***Decision-Making Practices & Policies:***

UWICER bases its project support decisions on the goals outlined in the 12th Five Year Plan for Bhutan, via robust evidence-based study and dissemination of scientific outcomes to field practitioners, environmental leaders, and policymakers. It aims to encourage better conservation of Bhutan's natural heritage-land, water, air, and wildlife. UWICER does not use any Earth Observations in their research or project planning process at the moment, but it is something they are looking into.

**Earth Observations & End Products Overview**

***Earth Observations Used:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Aqua MODIS** | Phenology | The MEaSUREs VIP phenology product was used to estimate the timing of vegetation phenology: vegetation growth, maturity, and senescence marking seasonal cycles from 1981 to 2014. |
| **Terra MODIS** | Phenology | The MEaSUREs VIP phenology product was used to estimate the timing of vegetation phenology: vegetation growth, maturity, and senescence marking seasonal cycles from 1981 to 2014. |
| **NOAA AVHRR** | NDVI | MEaSUREs NDVI preprocessed VIP data was used to derive phenology to estimate the timing of vegetation phenology: vegetation growth, maturity, and senescence marking seasonal cycles from 1981 to 2014. |

***Ancillary Datasets:***

* Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) – Gridded rainfall estimates from rain gauge and satellite observations. Data was used to assess trends in precipitation from 1981-2020
* Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System   
  (FLDAS) – Gridded temperature data used to assess trends in surface temperature from 1981-2020
* Height Above Nearest Drainage (HAND) – Reference mask for valley floors where absolute elevation is not consistent in the study area
* HEROES data – *in situ* data for phenology, temperature, and precipitation used to compare with Earth observations data

***Software & Scripting:***

* Google Earth Engine (GEE) API – Data visualization and raster manipulation
* Esri ArcMap 10.6 – Data visualization, raster analysis, and zonal statistics
* QGIS 3.16- Converting Hierarchical Data Format (HDF) to Geo Tiff. Clipping global data to team’s focus region- Bhutan.
* Panoply 4.11.1 – Data visual inspection
* Microsoft Office 365, Excel – Statistical analysis

***End Product(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Climate Trend Analysis** | N/A | The Climate Trend Analysis provides our partners with timely, objective, and spatially explicit meteorological data for land surface temperature and precipitation to understand trends in climate variability over the past 40 years. | III |
| **Phenology Maps from 1981-2014** | Terra MODIS, Aqua MODIS, AVHRR | Phenology maps show vegetation trends over the past 33 years from green-up to senescence. When correlated with meteorological records and *in situ* data, these maps provide the partners with estimates of changes in climate that impact vegetation in Bhutan. | III |

***Product Benefit to End User:***

This project will enhance the efforts of UWICER to recognize changes in climate for Bhutan. The Climate Trend Analysis and Phenology Maps will also support the HEROES project in understanding changes over the last 40 years for phenology and climatology by providing objective, timely, and spatially explicit Earth observation data. The maps and charts from the end products also serve as another monitoring tool to facilitate greater understanding and awareness of changes in phenology and climate in Bhutan.

***Project Continuation Plan:***

This term focused on expanding the previous project’s methods to the entire country. An analysis of potential changes in seasonality related to phenology and the climate analysis of precipitation and temperature for 40 years for the entire country was done. This project is expected to continue in Summer 2021, combining the work of the two previous terms to further identify relationships between climate and phenology focusing on agricultural impacts. This will help partners to meet their end goal in possibly identifying the rate of infection of forests and ways to predict diseases from forest pests.

**References**

Bhutan Foundation.(2020, July 30). *Home. https://www.bhutanfound.org/*

Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS): https://www.chc.ucsb.edu/data/chirps

Dorji, U., Olesen, J. E., Bøcher, P. K., & Seidenkrantz, M. S. (2016). Spatial variation of temperature and precipitation in Bhutan and links to vegetation and land cover. *Mountain Research and Development, 36*(1), 66-79. https://doi.org/10.1016/j.rsase.2020.100307

Height Above Nearest Drainage (HAND): https://gena.users.earthengine.app/view/global-hand

Himalayan Environmental Rhythm Observation and Evaluation System (HEROES):

http://www.heroes.gov.bt/web/index.php

Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System   
(FLDAS): https://ldas.gsfc.nasa.gov/fldas