Development of a near-real time hydrologic modelling system for India based on ensemble of SWAT model simulations

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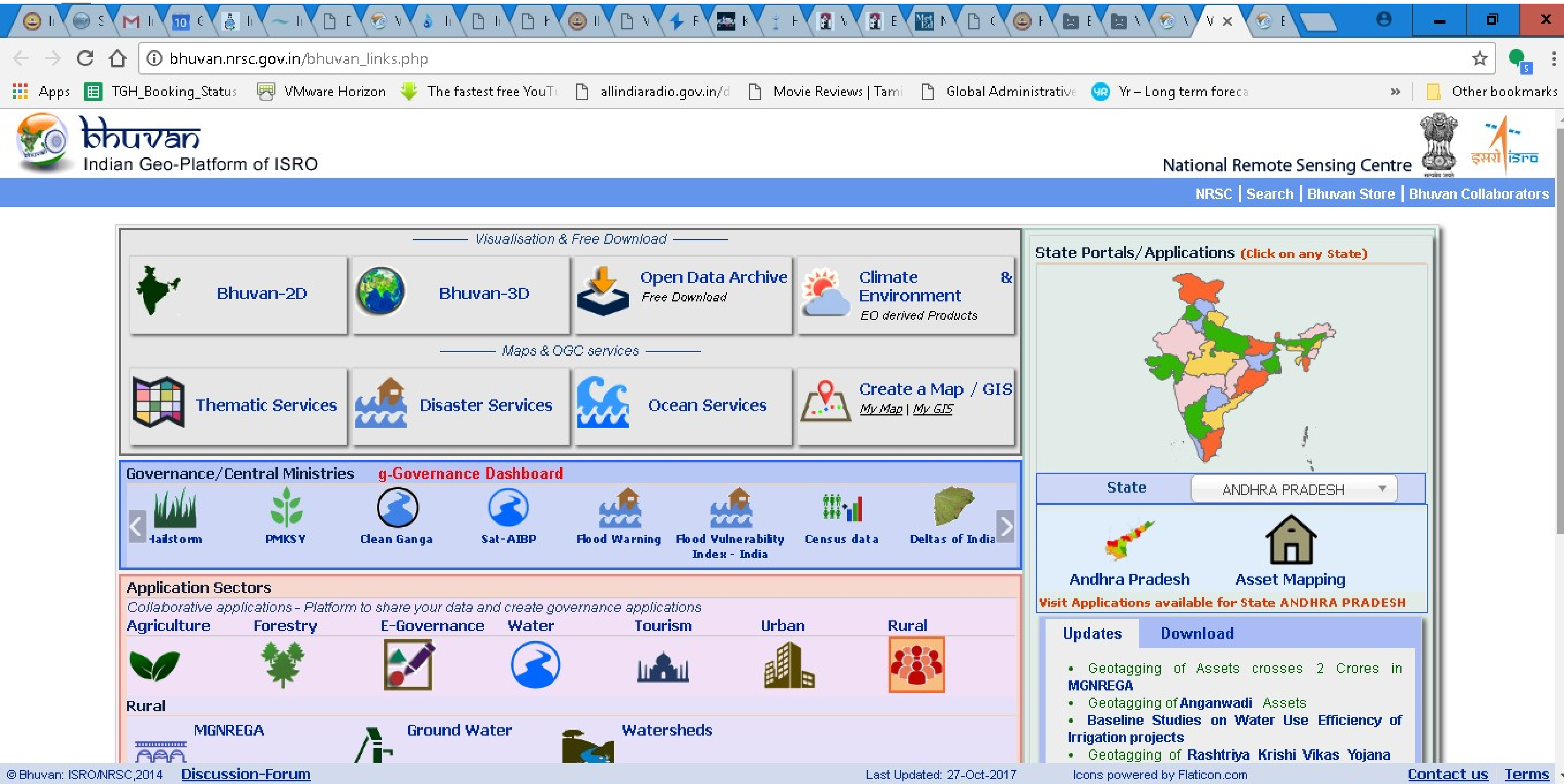
Motivation

- Spatially and temporally varying terrestrial water flux components are essential
  - *For water resources assessment, management and climate research studies*
- The availability of earth observation (EO) data from space
  - *From multitude of platforms*
    - for hydrological budgeting and modeling
- The model derived fluxes
  - *Periodic water budgeting in basin/sub-basin scale*
    - vital input for water resources management, land-atmosphere interactions including climate change etc….

National Information System for Climate & Environment Studies (NICES) by the National Remote Sensing Centre

- Quantifying the spatial and temporal distribution of water balance components
  - *to provide gridded estimates of hydrological fluxes through geo-spatial products at regular periodicity.*
- VIC Model in a gridded modelling frame
  - *This product provides spatial representation of water balance components over entire India on a particular day.*
    - 9min (~16.5km), 3min (~5.5km)
  - *This product is downloadable at daily time step in NetCDF format from NICES websites.*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Census data
Deltas of India
Application Sectors
Collaborative applications - Platform to share your data and create governance applications
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Forestry
E-Governance
Water
Tourism
Urban
Rural
Rural
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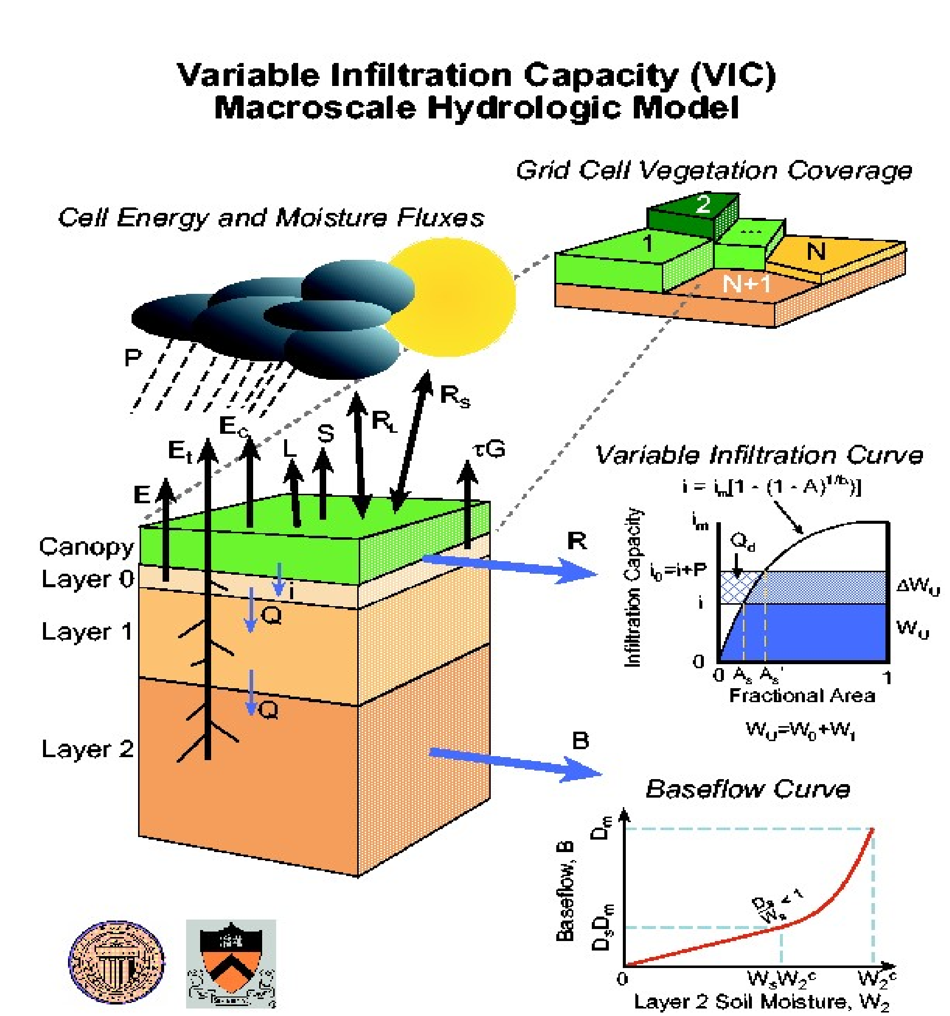
VIC MODEL



Source: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Overview/ModelOverview.shtml#SoilVeg

- Based on soil-vegetation-atmosphere transfer scheme.
- The land use is represented grid wise and the heterogeneity is accounted statistically
- arbitrary number of soil layers, but typically 3 and infiltration into the top-most layers controlled by variable infiltration capacity (VIC) parameterization
- VIC can use any combination of daily or sub-daily meteorological forcings, from point observations, gridded observations, or reanalysis fields.
- daily timeseries of land cover information such as albedo, LAI, and partial vegetation cover fraction as forcing variables.

DAILY OPERATIONAL PRODUCTS

Data Sources and related info.

Meteorological Data Source	Parameter	Resolution	Latency
IMD Gridded data	Rainfall, Min, Max Temperature	0.5 degree	1 day
IMD AWS data	Rainfall, Min, Max Temperature	Point data (interpolated to 9min/3min)	1 day
IMD high density data (Godavari & Mahanadi)	Rainfall	Point data (interpolated to 3min)	1 day
CPC	Rainfall	0.1 degree	2 days
GEFS	Rainfall, Min, Max Temperature	0.5 degree (interpolated to 9min/3min)	Daily forecast data
APSDPS AWS data	Rainfall, Min, Max Temperature	Point data (interpolated to 3min)	1 day

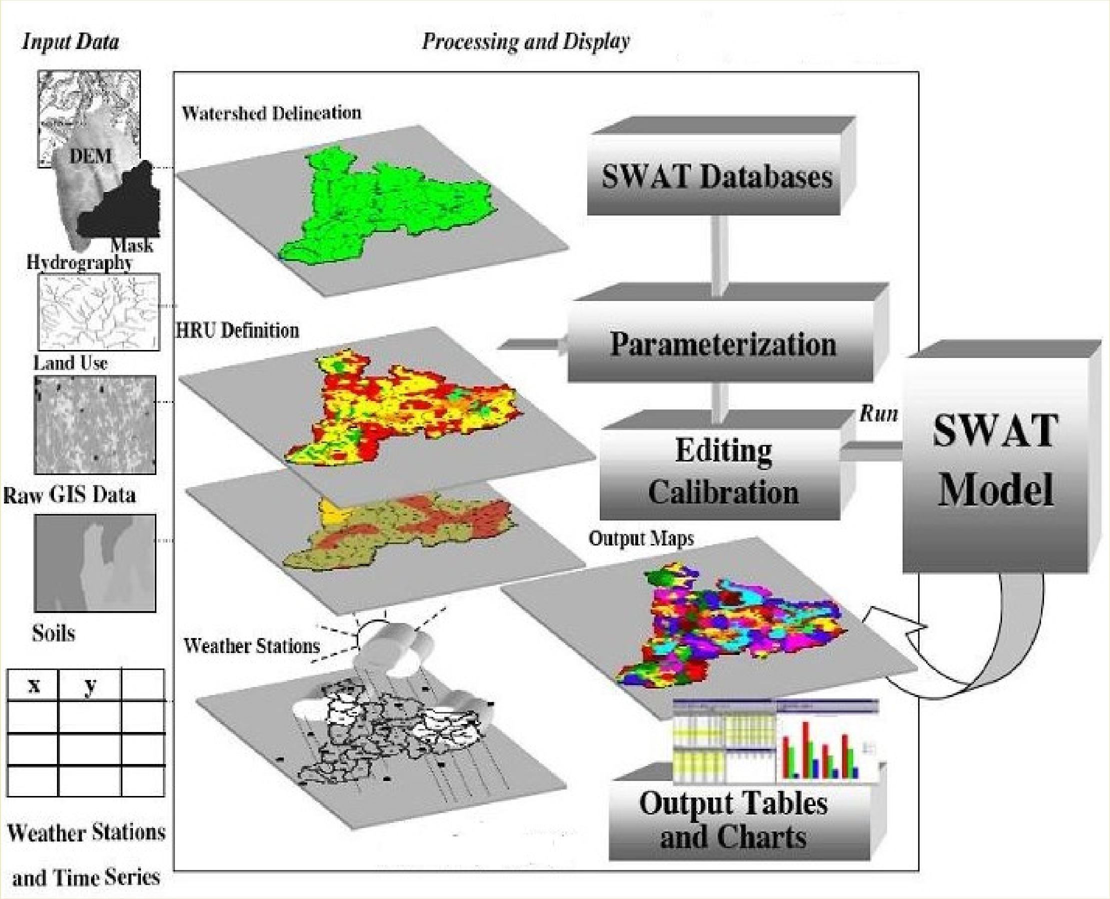
Web Published VIC Model Derived Products

Product	Resolution	Frequency
Water Balance Components for entire India	3min (~5.5km), 9min (~16.5km)	Daily
Forecast Surface Runoff (d*+3)	9min (~16.5km)	Daily
Accumulated Surface Runoff	9min (~16.5km)	Daily
Climate Indices – SPI , SRI (1, 3, 6, 12 Months)	9min (~16.5km)	Daily
River Basin Wise Statistics	-	Weekly
WBC's for Godavari, Mahanadi River	3min (~5.5km)	Daily

Lacuna of the current modeling system

- Assumes virgin basin conditions
  - *Irrigation diversions, storage structures and other hydraulic interventions are not included*
- Irrigation water requirements are not taken into account for hydrologic process simulations
- Cropping cycle based on long-term vegetation index
  - *Variability in cropping cycle during normal year, wet year and dry year is difficult to incorporate*

SWAT MODEL



Source: https://geo.arc.nasa.gov/sge/casa/hydrologic/swat.html

- Conceptual, hydrologic Semi distributed continuous model with spatially explicit parameterization
- The SWAT discretizes watershed into sub-basin and then to unique landuse/ management/soil attribute called HRU
- Sub-basin level spatial interactions exists and the HRU increase the accuracy of prediction of loadings from sub-basin.
- SWAT can account infiltration through different soil layers and deep percolation
- Flexibility to setup the model in user defined spatial scale,

Using SWAT to address the lacuna

- Model development incorporating all major hydraulic interventions
  - *Including irrigation diversions*
- Dynamic simulation of irrigation water requirement based on crop demand
- Development of crop management input for the entire country by developing an automated algorithm
  - *Gridwise typical cropping cycle(s)*
    - Sowing, maturity, harvest dates

STUDY AREA

Gridded **SWAT model to be developed for the entire country**

1) 3min (~5km) and

3) 1km.

KRISHNA RIVER BASIN DETAILS:

Area of the Basin:2,58,948 sq.km

Area extent: Karnataka, Telangana, Andhra and Maharashtra

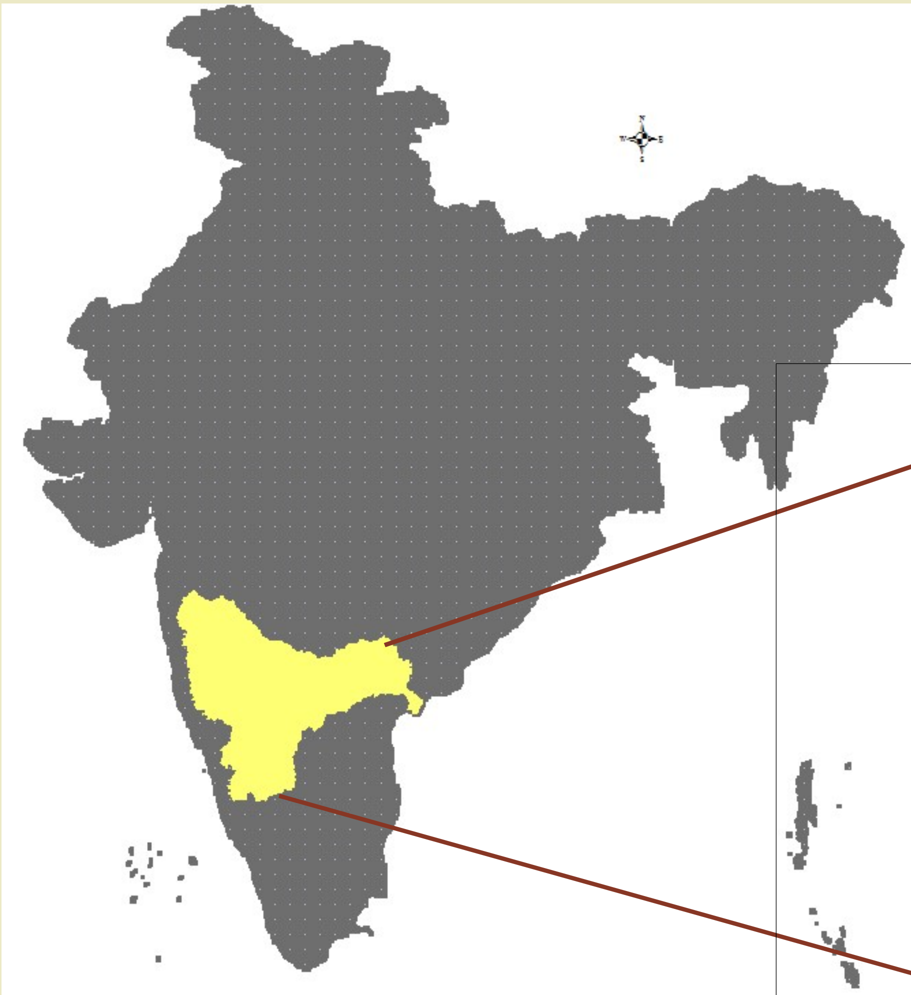
Average annual Rainfall : 784mm

Agricultural land: 75.86% of Total area

Major crops: Rice, jowar, sugarcane, millets, corn, grass folder and variety of horticultural crops

No. of Dams : 668 dams & 90% of dam is for irrigation purpose

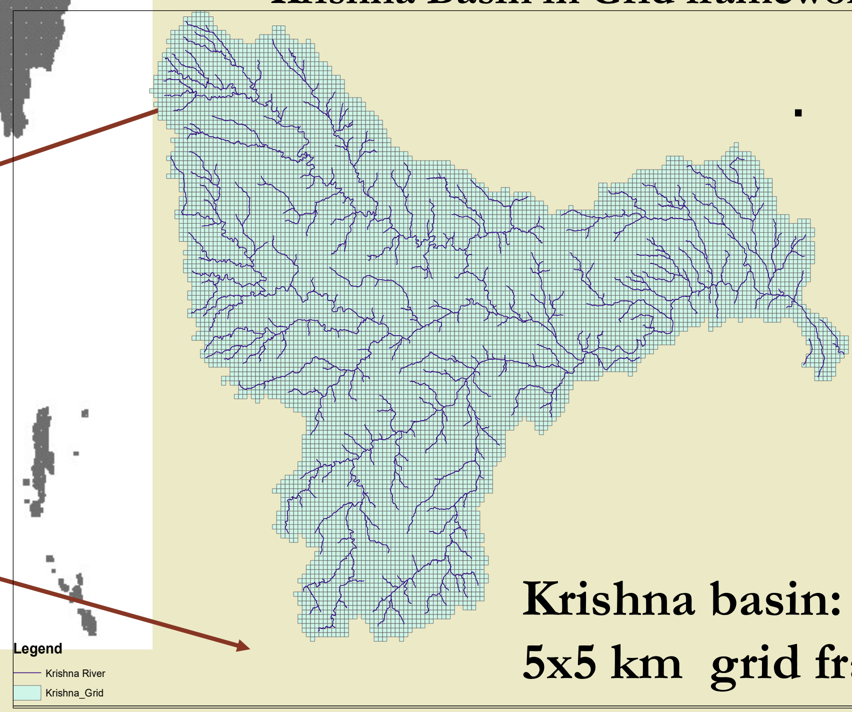
5.0 x 5.0km Grid framework for India



5x5 km grid cells: 1,60,323

1 x1km grid cells: 40,08,075

Krishna Basin in Grid framework

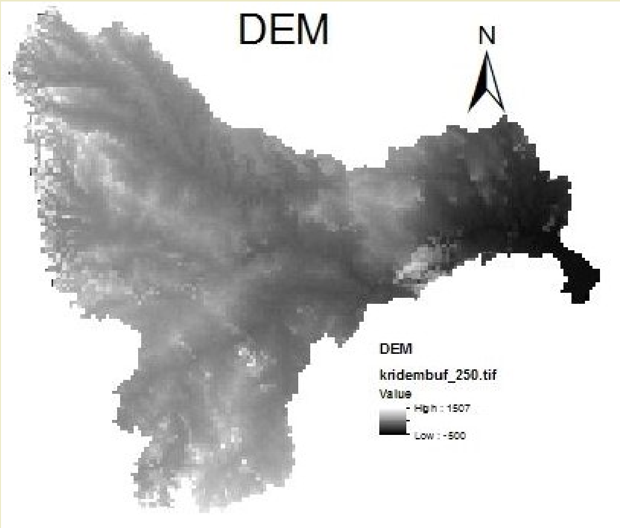


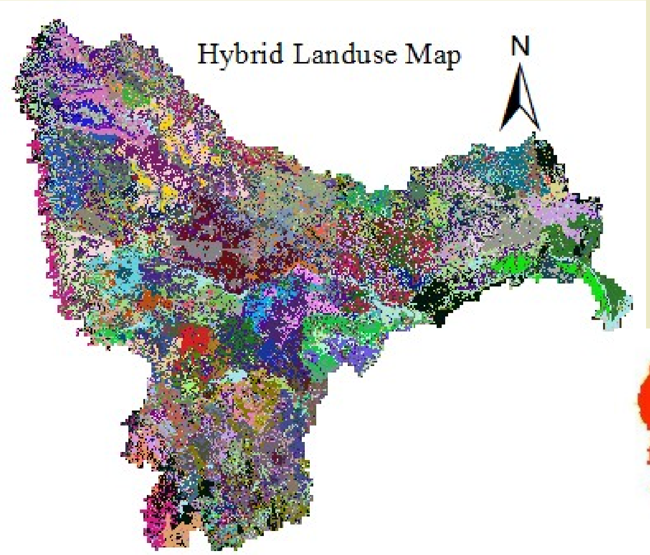
Krishna basin:

5x5 km grid framework: 10410

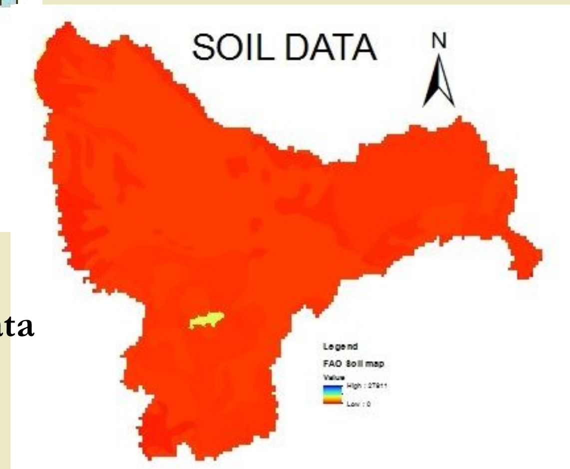
Gridded model setup for Krishna Basin

Digital Elevation Model, Landuse, and soil data to be resampled to 250m spatial resolution to carry out the watershed delineation



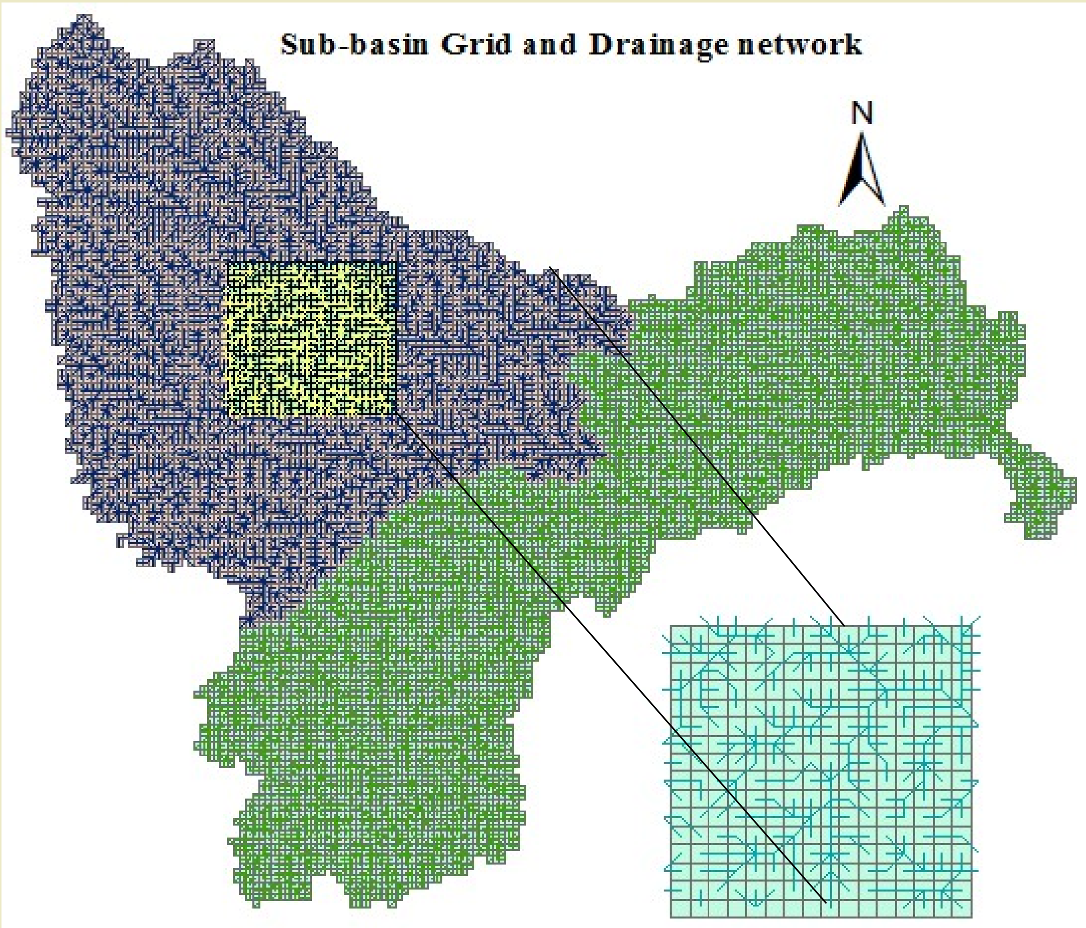


Hybrid Landuse map describing unique Landuse for each district representing Crop season and irrigation scenarios

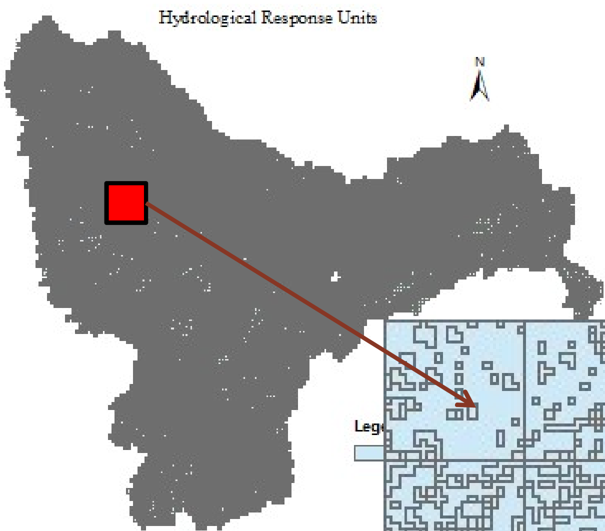


Global FAO soil data

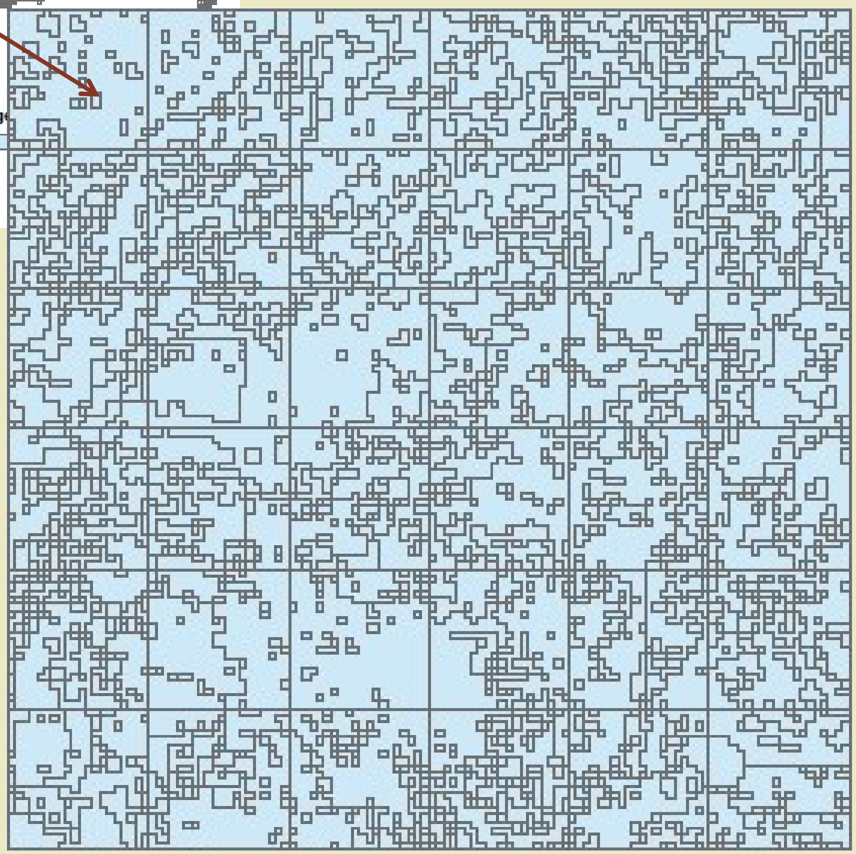
PREDEFINED SUB-BASIN GRIDS AND STREAM NETWORKS



- **5x5 km grid framework= 10410**
  - *For ease of data handling the watershed is splitted into two sub-watersheds with*
    - **Upper Krishna having grids 5158**
    - Lower Krishna having 5261
- **The outlet from the upper basin is provided as inlet discharge and overall water balance is computed.**

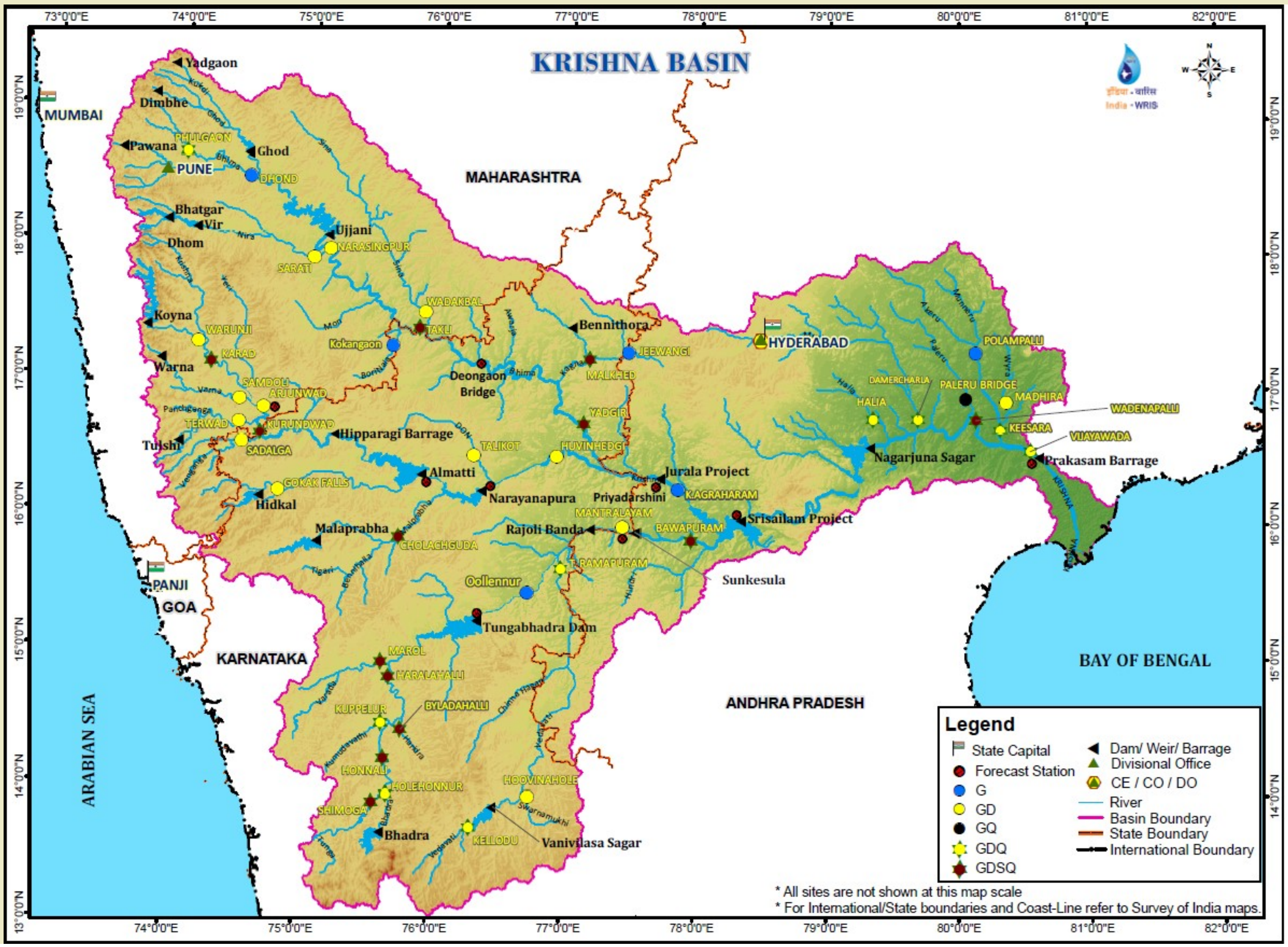


ROLOGICAL RESPONSE UNIT



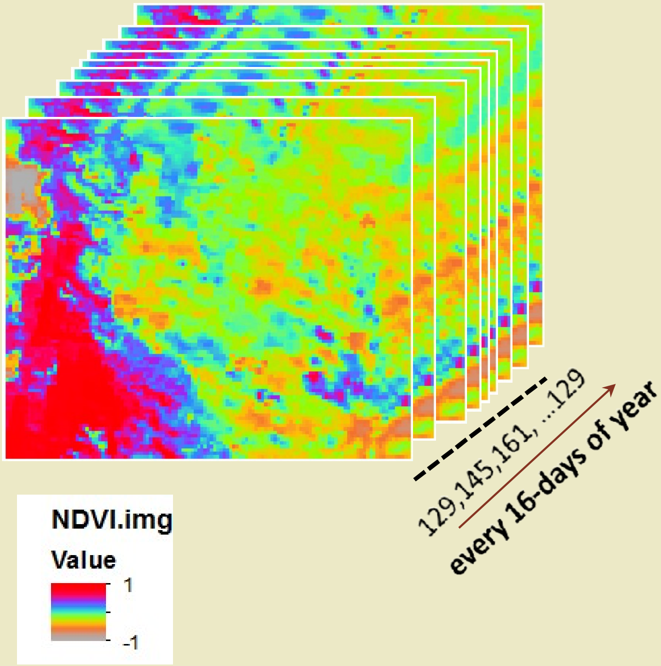
- Every grid will be simulated with multiple hydrologic response units (HRU's).
  - *Filter by area threshold of 100 ha*
    - Upper Krishna = 26,533
    - Lower Krishna = 25,131
- For the model set-up at 1km resolution, each grid (sub-basin) will be modelled with a single dominant HRU within the grid

Hydraulic Interventions

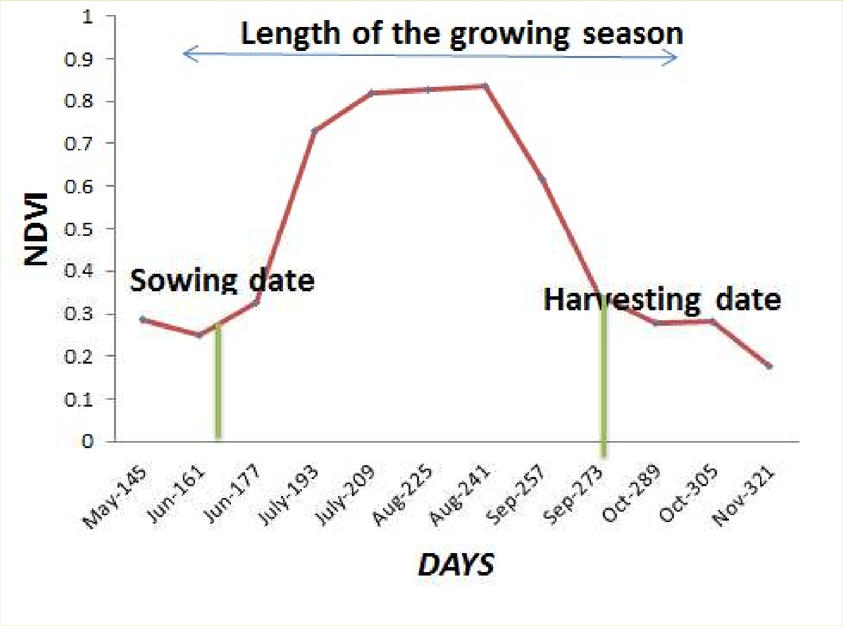


EXTRACTION OF CROP PHENOLOGICAL PARAMETERS FOR SWAT MANAGEMENT PRACTICES

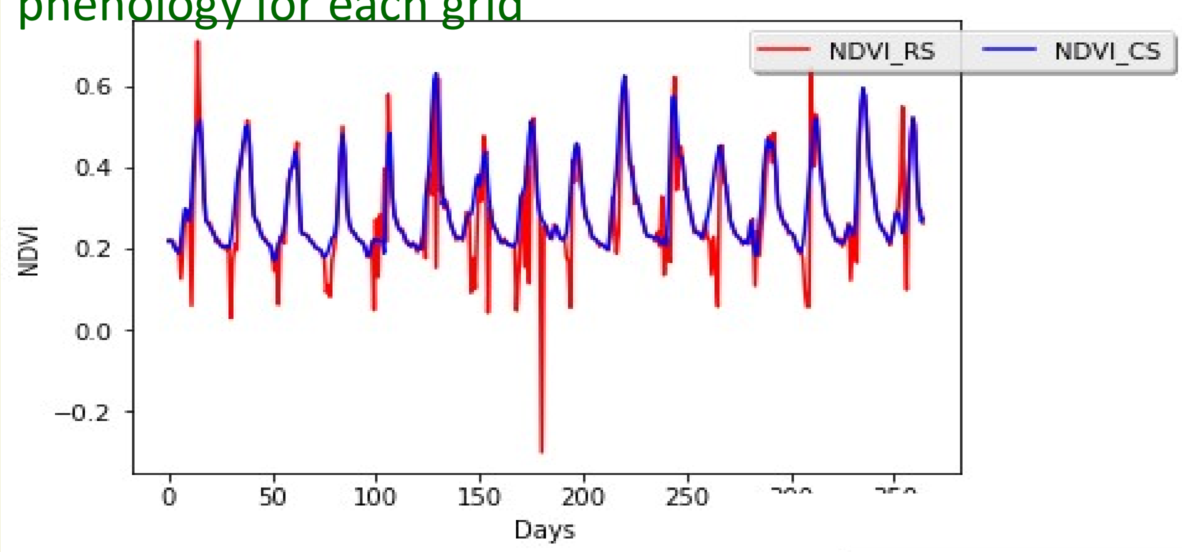
MODIS VI LAYERSTACKING



NDVI profile of a Rice crop

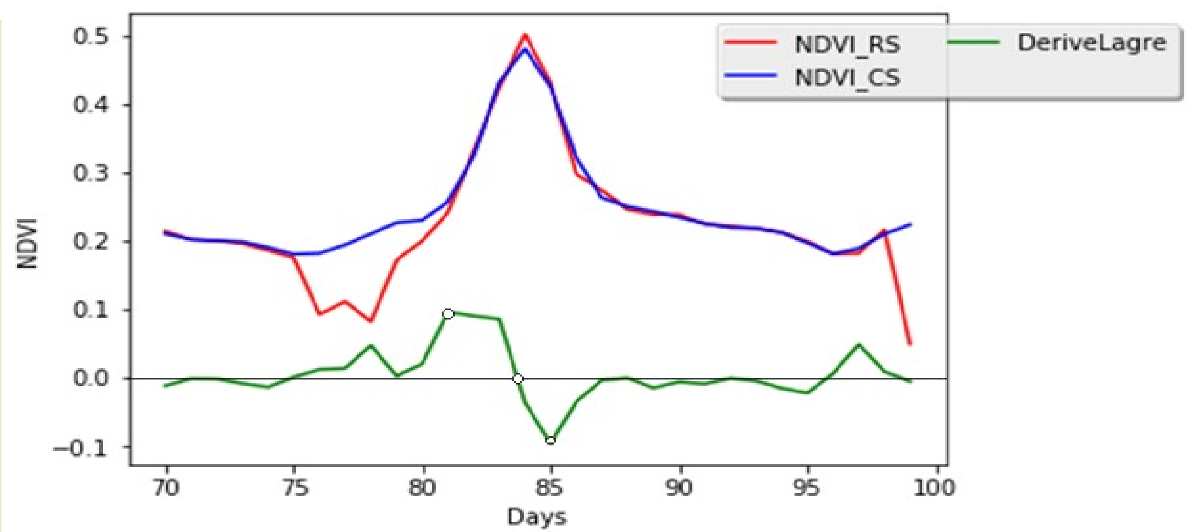


Development of an automated algorithm for identifying critical crop cycle and crop phenology for each grid



Noise corrected smoothened NDVI profile for 15 years 2000_2015

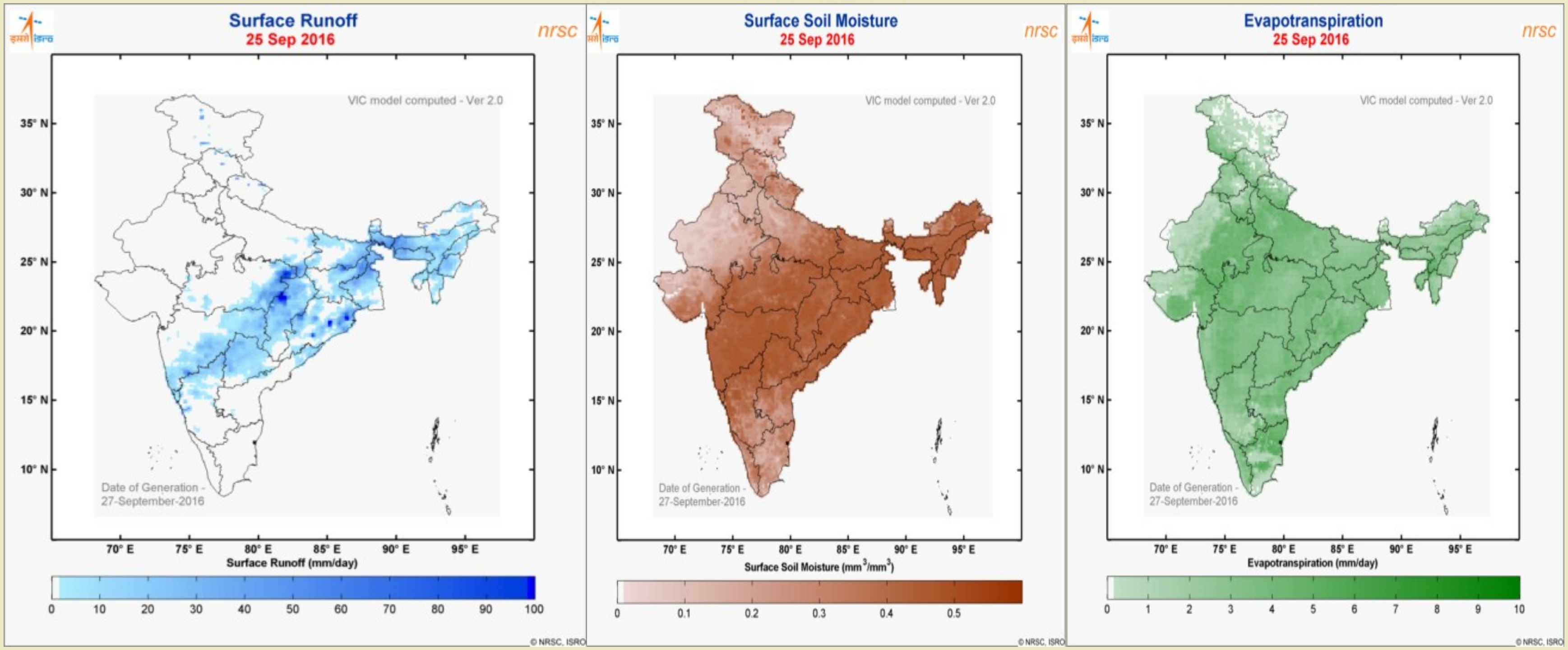
First Derivative of 3-point Lagregian Interpolation is applied to estimate the sowing and harvesting dates and crop growth period



SWAT MODEL CALIBRATION

- Observed streamflow data
- Remotely sensed ET
  - *Each subbasin/grid simulated evapotranspiration and soil moisture calibrated using*
    - MODIS (MOD16) 1km, 8-day composite ET data and
    - AMSRE-2 0.25deg , 2-days soil moisture

Hydrological Science
Near Real Time Hydrological Modelling - Products & Services



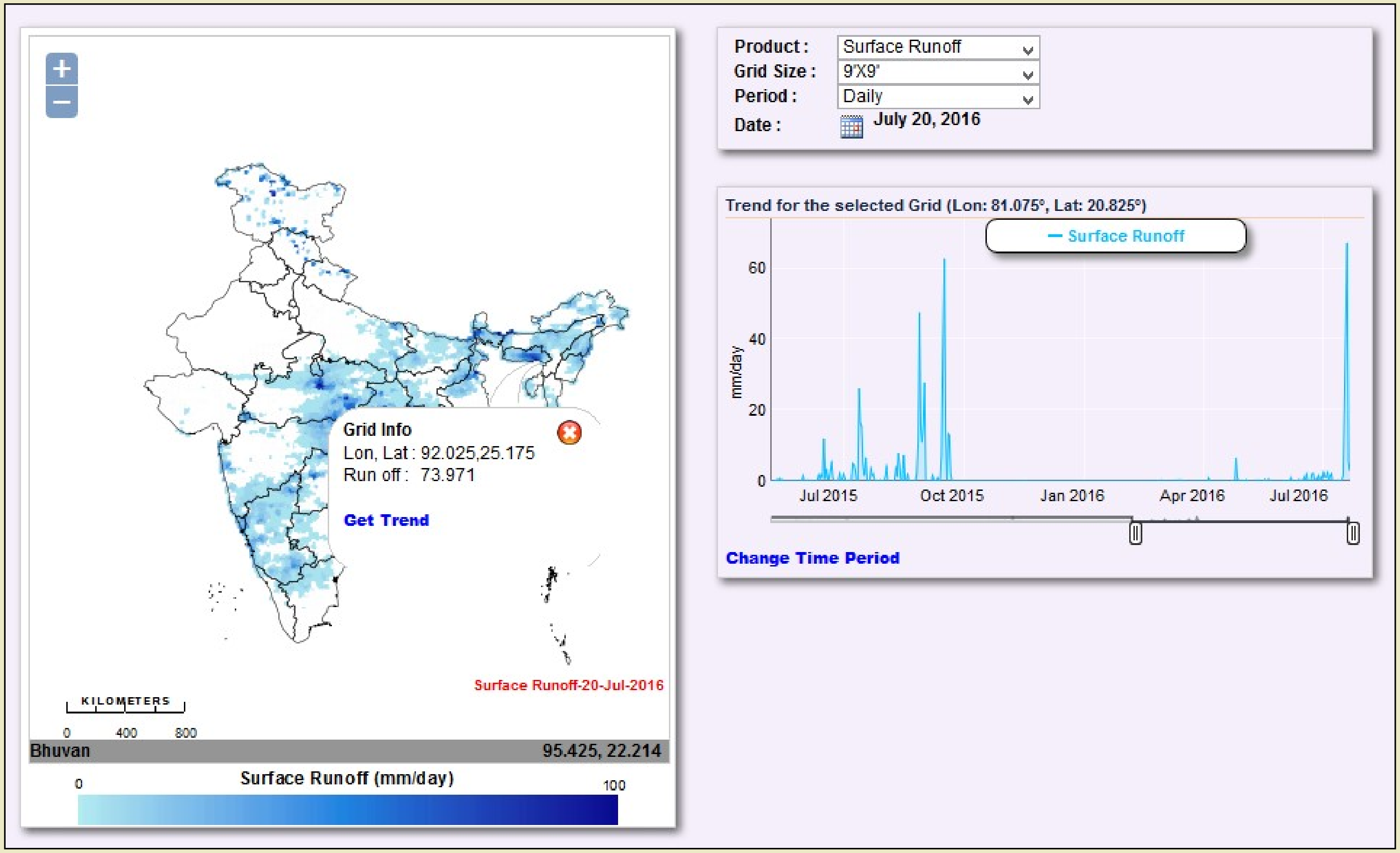
VIC-3L hydrological model considering geo-spatial data and current season meteorological data. Runoff and Evapotranspiration are represented in mm and Soil Moisture is represented in m^3/m^3. All the products are averaged at 9 min (~16.5 km) spatial resolution at 24 hr time-step.

Source: http://bhuvan.nrsc.gov.in/nices/#nices9

Hydrological Science

Near Real Time Hydrological Modelling - Products & Services

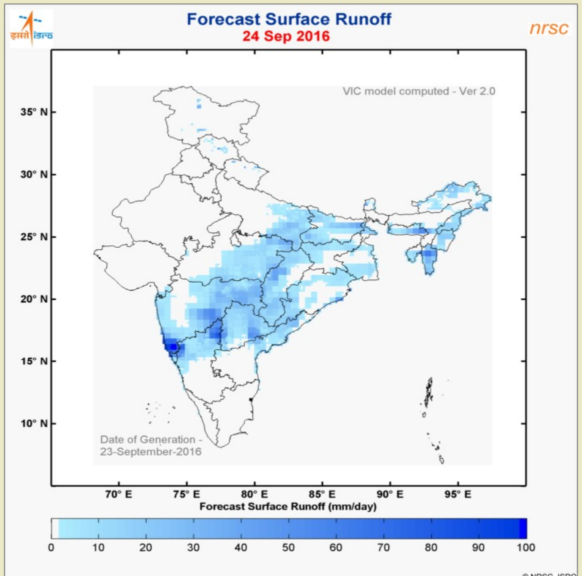
Grid Wise Time Series Visualization

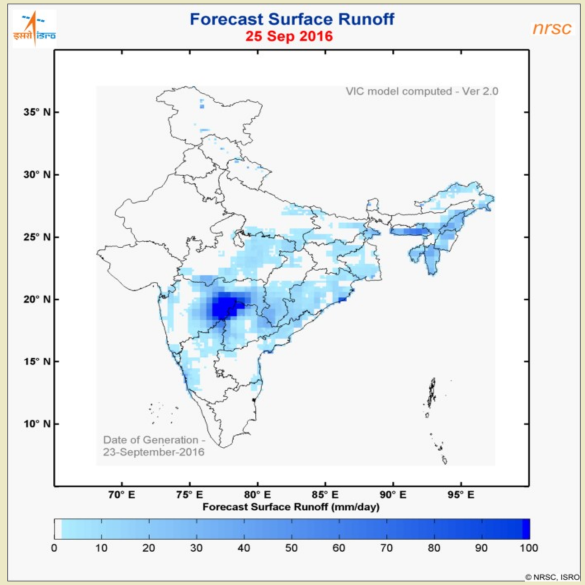


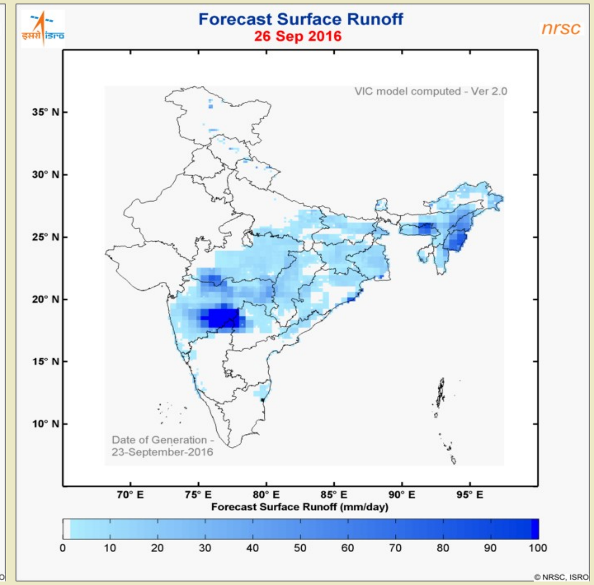
- Utility: Temporal variation of WBC's at any grid can be visualized.

Hydrological Science
Near Real Time Hydrological Modelling - Products & Services

Forecast Surface Runoff







Details and Features

- Surface runoff forecast is presented for three successive days (d+1, d+2, d+3, where d = Current date) using weather forecast data (Rainfall and Temperature) from the Global Ensemble Forecast System (GEFS/R2 – *http://www.esrl.noaa.gov/psd/forecasts/reforecast2/download.html*).
- Forecasted Surface Runoff products depict the likely runoff depth at each grid level in mm depth units.
- Utility: Forecasted Surface Runoff and its spatial distribution for 3 days lead time is useful for disaster management operations. This product was provided to DMSG group NRSC during 2016 monsoon season.

Source: http://bhuvan.nrsc.gov.in/nices/#nices9

EXPECTED OUTOMES

- Modelling and mapping of water flux throughout the country using gridded SWAT model by incorporating major hydraulic interventions
- Development of an automated algorithm to derive cropping calendar and management practice files for the entire country
- Development of highly probable model ensembles to assist in better decision making

THANK YOU!