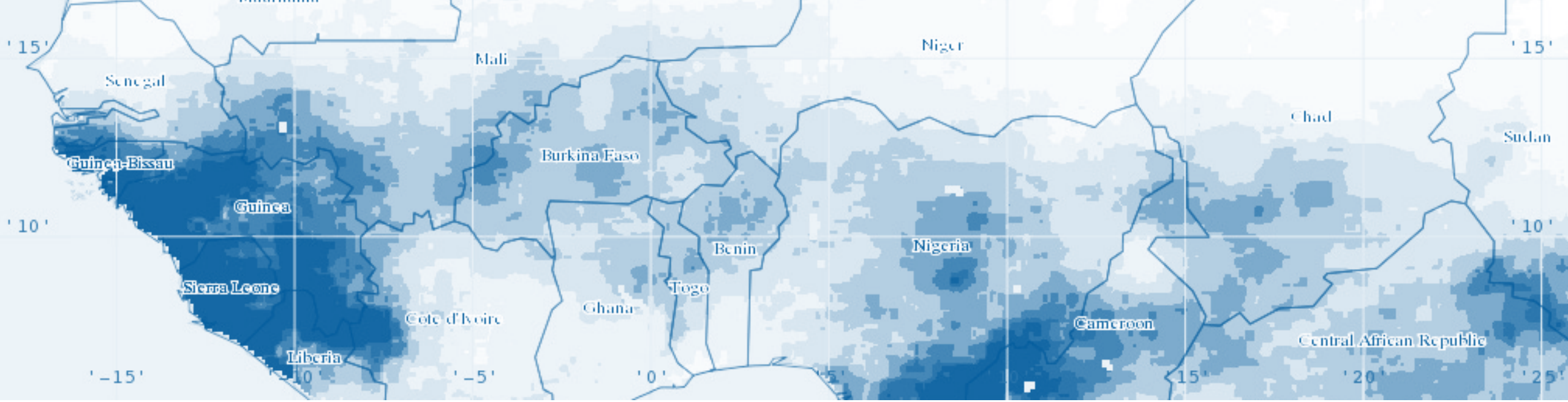


# VIC DATA INPUTS AND OPTIONAL PROCESSES

Kel Markert

NASA-SERVIR Mekong Regional Associate

University of Alabama in Huntsville | Earth System Science Center

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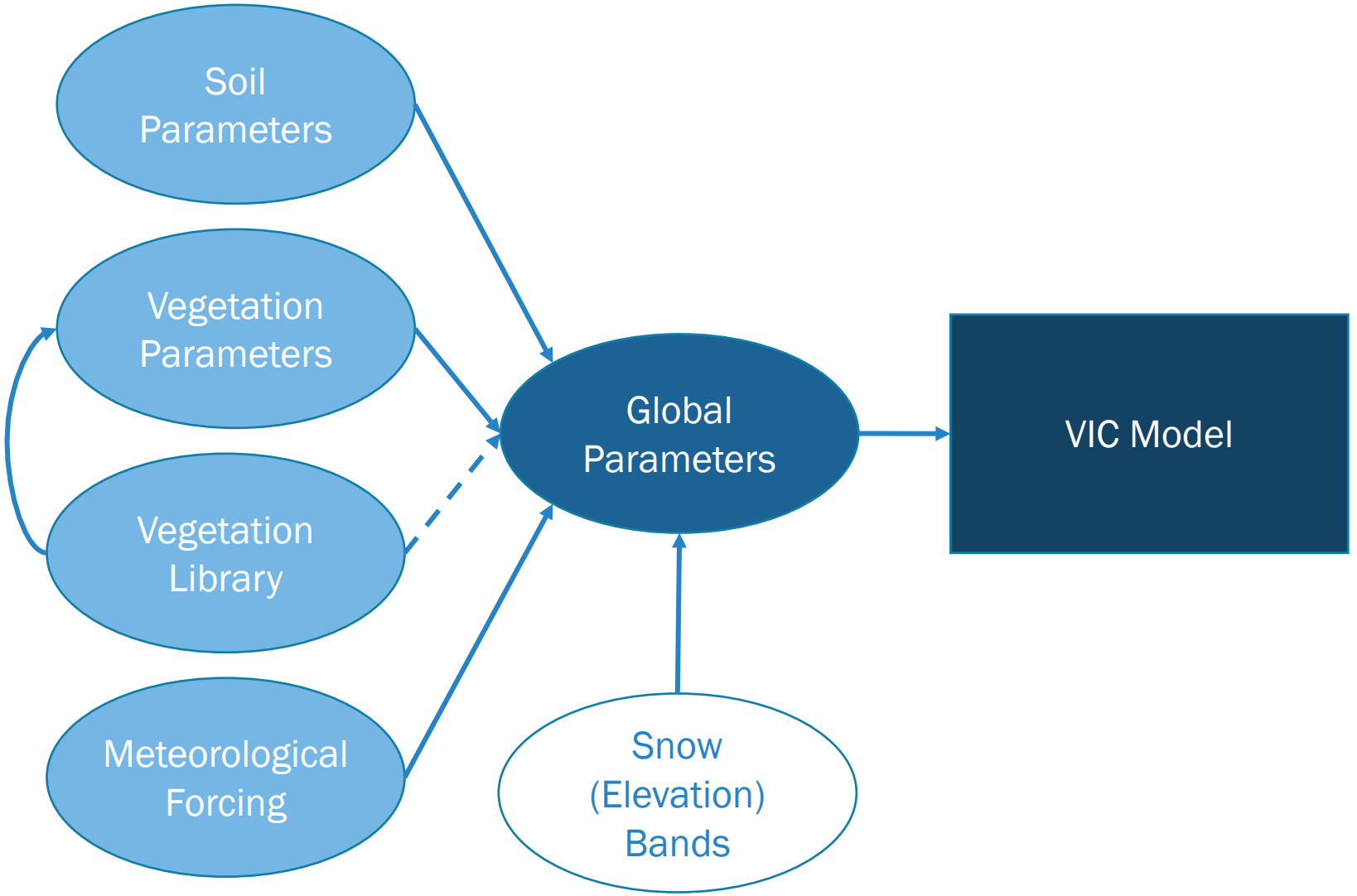
VIC/BCSPP Training

Huntsville, AL

# VIC MODEL INPUTS

- The VIC model is complex requiring large amount of data in stored in multiple files
- Much of the data can be acquired from remote sensing/GIS data sets



# GLOBAL PARAMETER FILE

- Main input file for VIC
- Sets some model parameters and options
- Points VIC to the locations of other input/output file
- Sets parameters that govern the simulation
  - Start/end dates
  - Model modes
  - Physical processes

```
################################################################################
# VIC Model Parameters - 4.2.x
################################################################################
# $Id$
################################################################################
# Simulation Parameters
################################################################################
NLAYER  3   # number of soil layers
NODES       10  # number of soil thermal nodes
TIME_STEP   24  # model time step in hours (set to 24 if FULL_ENERGY = FA
SNOW_STEP   24  # time step in hours for which to solve the snow model (s
STARTYEAR   1980 year model simulation starts
STARTMONTH  01  # month model simulation starts
STARTDAY    01  # day model simulation starts
STARTHOUR   00  # hour model simulation starts
ENDYEAR     2010 year model simulation ends
ENDMONTH    12  # month model simulation ends
ENDDAY  31  # day model simulation ends

################################################################################
# Energy Balance Parameters
################################################################################
FULL_ENERGY     FALSE   # TRUE = calculate full energy balance; FALSE = c
CLOSE_ENERGY    FALSE   # TRUE = all energy balance calculations (canopy
                        # and ground surface) are iterated to minimize th
```

- Global parameter file documentation: http://vic.readthedocs.io/en/master/Documentation/Drivers/Classic/GlobalParam/

# SOIL PARAMETER FILE

- Defines the spatial representation of the model
  - Grid cell ID
  - Latitude/longitude
- Model links the rest of data inputs through soil file by using grid cell ID
- Defines soil parameters at surface and each depth
- Defines initial soil moisture conditions when no state file is used

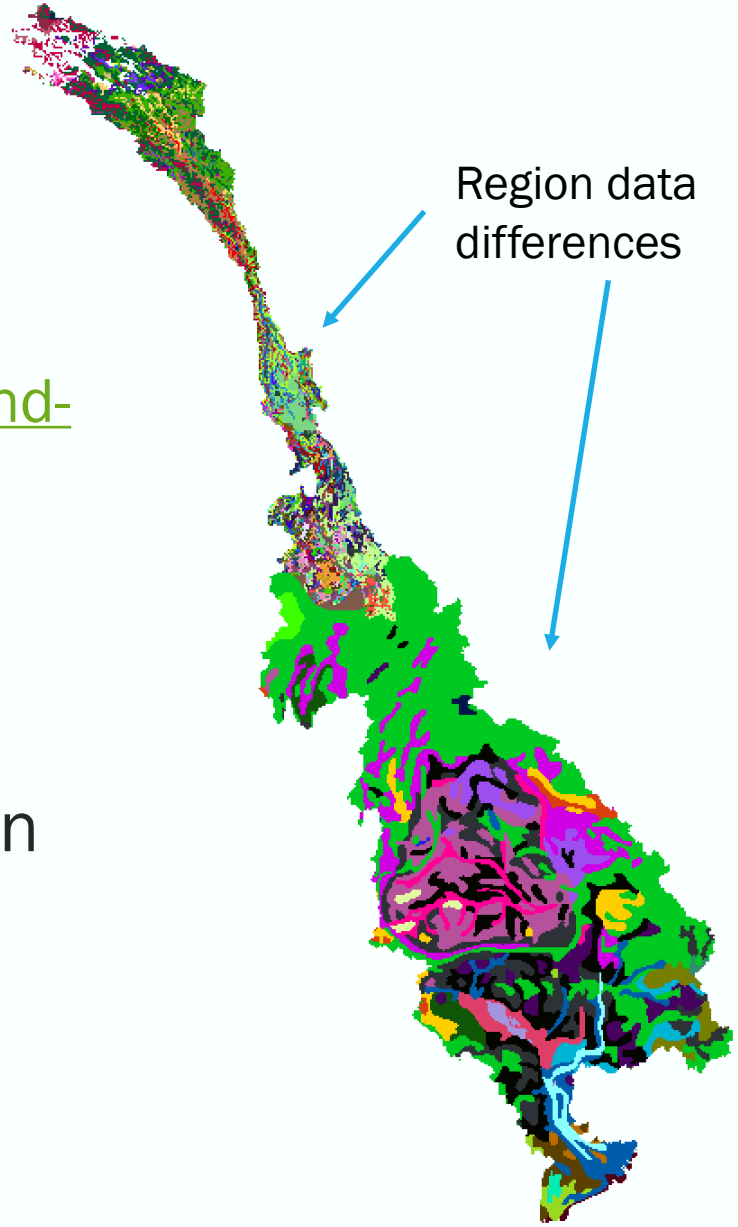
Run value
Grid cell ID
Lat/Lon
Soil parameters

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4373 | 15.6058 107.0932 | 0.125 | 0.325 | 94.0823 | 0.96 | 2 | 13.6 | 13.6 | 13.6 |
| 1 | 4374 | 15.6058 107.3454 | 0.125 | 0.325 | 60.8905 | 0.96 | 2 | 13.6 | 13.6 | 13.6 |
| 1 | 4411 | 15.3546 101.5466 | 0.1 | 0.3 | 8.8226 | 0.95 | 2 | 20.32 | 19.04 | 19.04 | 576.0 |
| 1 | 4412 | 15.3546 101.7987 | 0.15 | 0.35 | 2.9614 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4413 | 15.3546 102.0509 | 0.1 | 0.3 | 3.4251 | 0.95 | 2 | 20.32 | 19.04 | 19.04 | 576.0 |
| 1 | 4414 | 15.3546 102.3030 | 0.1 | 0.3 | 2.7713 | 0.95 | 2 | 20.32 | 19.04 | 19.04 | 576.0 |
| 1 | 4415 | 15.3546 102.5551 | 0.15 | 0.35 | 2.0940 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4416 | 15.3546 102.8072 | 0.15 | 0.35 | 1.8068 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4417 | 15.3546 103.0593 | 0.15 | 0.35 | 1.7430 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4418 | 15.3546 103.3115 | 0.15 | 0.35 | 1.2203 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4419 | 15.3546 103.5636 | 0.15 | 0.35 | 0.9377 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4420 | 15.3546 103.8157 | 0.15 | 0.35 | 1.0616 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |
| 1 | 4421 | 15.3546 104.0678 | 0.15 | 0.35 | 1.2873 | 0.975 | 2 | 13.6 | 19.04 | 19.04 |

- Soil parameter file documentation: http://vic.readthedocs.io/en/master/Documentation/Drivers/Classic/SoilParam/

# SOIL DATA

- Soil information is poorly know
- Harmonized World Soil Database (HWSD)
  - 30 arc-second (~1km) raster database
  - Classified raster grid with database look-up information
  - http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/
- Contains over 15,000 different soil mapping units
  - Has multiple soil parameters per mapping unit
  - **Used for soil pedotransfer functions**
- Accuracy and mapping information differs by region
  - Example: Lower vs Upper Mekong



# VEGETATION PARAMETER FILE

- Defines land cover types present and fractional areas for a grid cell
- Also define rooting depths and rooting distributions for each land cover type
- Optional parameter setting:
  - Blowing snow
  - LAI
  - Vegetation cover
  - Albedo

```
2 1
    10 1.0000 0.1 0.1 1.0 0.65 0.5 0.25
3 1
    10 1.0000 0.1 0.1 1.0 0.65 0.5 0.25
4 3
    10 0.9759 0.1 0.1 1.0 0.65 0.5 0.25
    15 0.0238 0.1 0.1 0.5 0.8 0.25 0.1
    16 0.0003 0.1 0.1 0.75 0.8 0.25 0.1
```

Grid cell ID

Number of vegetation classes

Vegetation class

Fractional cover

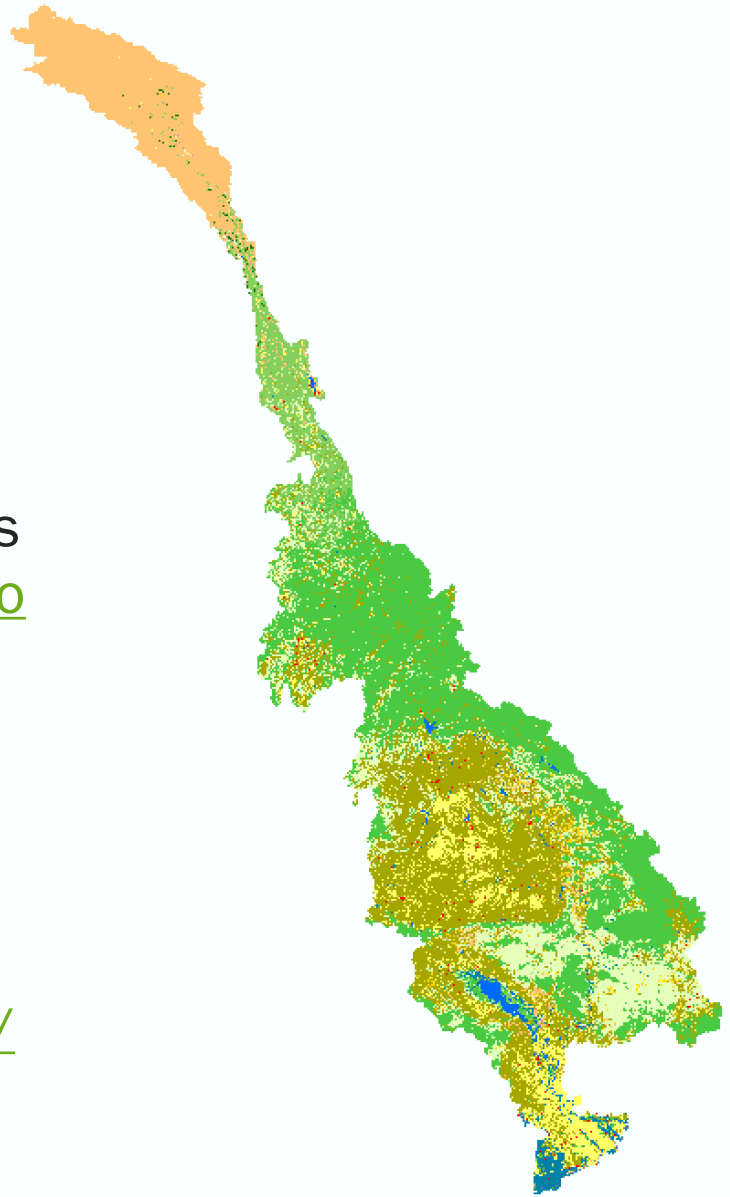
Rooting depths

Root distribution

- Vegetation parameter file documentation: http://vic.readthedocs.io/en/master/Documentation/Drivers/Classic/VegParam/

# LAND COVER DATA AND PARAMETERIZATION

- Can use whichever land cover dataset/classification best fits your needs
  - Create vegetation parameter file
  - Extract information for vegetation library
- MODIS Combined Land Cover Product (MCD12Q1) IGBP classification
  - Fairly accurate mapping at global scale
  - Existing land cover parameterizations for land surface models
  - https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1
- Create your own land surface parameterization scheme or use existing
  - NCAR NOAH LSM parameterizations
  - http://www.ral.ucar.edu/research/land/technology/noahmp/HRLDAS-v3.6/VEGPARM.TBL



# VEGETATION LIBRARY FILE

- Defines land parameterization for model
  - Parameterization provided for each possible land cover class
  - Library file referenced by vegetation parameter file

| #Class | OvrStry | Rarc | Rmin | JAN-LAI | FEB-LAI | MAR-LAI | APR-LAI | MAY-LAI | JUN-LAI | JUL-LAI |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 2 | 100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 | 0.0100 |
| 1 | 1 | 25 | 125 | 1.5961 | 2.1136 | 2.0729 | 1.9686 | 2.1282 | 5.6069 | 4.2471 | 5.1727 | 2.8051 |
| 2 | 1 | 25 | 150 | 4.4867 | 4.2909 | 4.2895 | 4.5333 | 4.8896 | 5.6081 | 7.7333 | 6.2693 | 5.4424 |
| 3 | 1 | 40 | 150 | 2.2937 | 2.3407 | 2.4277 | 2.4511 | 2.6480 | 3.3034 | 3.9435 | 4.0696 | 3.1522 |
| 4 | 1 | 40 | 100 | 2.1418 | 1.9763 | 1.9232 | 2.3924 | 3.5952 | 4.5133 | 5.7999 | 4.8241 | 4.0229 |
| 5 | 1 | 30 | 125 | 1.3690 | 1.3749 | 1.4390 | 1.8477 | 2.5444 | 3.3740 | 4.2285 | 4.0718 | 3.2090 |
| 6 | 1 | 5 | 300 | 1.2059 | 1.2159 | 1.2265 | 1.3351 | 1.5659 | 1.8995 | 2.4379 | 2.3064 | 2.1375 |
| 7 | 0 | 5 | 300 | 2.2195 | 2.6237 | 2.4234 | 2.5169 | 1.9013 | 2.3658 | 2.8642 | 4.0304 | 2.5215 |
| 8 | 1 | 3 | 300 | 2.0767 | 1.8409 | 1.8251 | 2.1473 | 2.6409 | 3.3774 | 4.9482 | 4.1420 | 3.6329 |
| 9 | 0 | 3 | 70 | 2.3547 | 2.1610 | 2.1781 | 2.3227 | 2.6348 | 3.1140 | 3.8399 | 3.2703 | 3.3249 |
| 10 | 0 | 2 | 40 | 1.1553 | 1.2717 | 1.3669 | 1.4002 | 1.3733 | 1.8452 | 2.4907 | 2.6893 | 1.8668 |
| 11 | 0 | 2 | 70 | 4.5140 | 4.4848 | 4.2690 | 4.3764 | 4.5761 | 4.8642 | 5.3228 | 4.9195 | 4.7831 |
| 12 | 0 | 2 | 40 | 1.3742 | 1.3760 | 1.4028 | 1.5861 | 1.7493 | 2.0283 | 2.3606 | 2.2641 | 2.1590 |
| 13 | 0 | 2 | 200 | 3.7206 | 3.5631 | 3.2303 | 3.4365 | 3.2502 | 3.7628 | 4.4424 | 4.4719 | 4.0467 |
| 14 | 0 | 2 | 40 | 1.7629 | 1.6556 | 1.6839 | 1.8319 | 2.0875 | 2.4213 | 2.8160 | 2.5959 | 2.6465 |
| 15 | 0 | 2 | 999 | 7.8138 | 9.0695 | 8.9222 | 8.0405 | 3.8058 | 4.0207 | 3.4044 | 6.7843 | 3.9934 |
| 16 | 0 | 2 | 999 | 4.5344 | 4.6429 | 4.1192 | 4.2679 | 3.9064 | 4.3898 | 4.6674 | 4.7253 | 4.2931 |

Header information
Class 1 parameterization
Class 2 parameterization
Class n parameterization

- Vegetation library file documentation: http://vic.readthedocs.io/en/master/Documentation/Drivers/Classic/VegLib/

# LAND SURFACE PARAMETERIZATION

- Use observed remote sensing datasets to create your own land surface parameterizations
  - Need monthly climatology information for albedo and LAI parameters
- MODIS LAI and albedo products (2000-present)
  - LAI: https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod15a2
  - Albedo: http://modis-atmos.gsfc.nasa.gov/ALBEDO/index.html
- Can use remote sensing datasets for vegetation height, surface roughness, etc.
  - Large errors with derived data
  - Can lead to errors in model
- *Should you use observed remote sensing data or existing parameterization?*

# ELEVATION BAND FILE

- Not a required input
- Used to partition grid cell into different elevation for more accurate orographic effects
- Set maximum number of elevation band
  - Each grid needs the maximum number of bands specified (fill non-existant bands with zeros)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 0.7139 | 0.2561 | 0.0263 | 0.0037 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1256.9296 | 1335.9584 | 1427.7449 | 1531.3063 | 0.0000 | 0. |
| 8 | 0.1918 | 0.5602 | 0.1446 | 0.0907 | 0.0126 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1282.4463 | 1342.8496 | 1446.6097 | 1539.5243 | 1629.3716 | |
| 9 | 0.3913 | 0.4651 | 0.1265 | 0.0171 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1377.0970 | 1437.1366 | 1540.3333 | 1633.3934 | 1703.0000 | |
| 10 | 0.2079 | 0.3771 | 0.2244 | 0.1097 | 0.0519 | 0.0185 | 0.0101 | 0.0003 | 0.0000 | | | | | | |
| 11 | 0.0022 | 0.0744 | 0.1235 | 0.1223 | 0.2079 | 0.3223 | 0.1405 | 0.0069 | 0.0000 | | | | | | |
| 13 | 0.1778 | 0.2938 | 0.3229 | 0.1657 | 0.0399 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | | |
| 14 | 0.0369 | 0.1398 | 0.7016 | 0.1212 | 0.0005 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | | |
| 15 | 0.0002 | 0.2228 | 0.3332 | 0.3470 | 0.0968 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | | |
| 16 | 0.0413 | 0.6030 | 0.2201 | 0.1247 | 0.0108 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | | |
| 17 | 0.0338 | 0.4448 | 0.4322 | 0.0891 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | | | | | | |

Grid cell ID

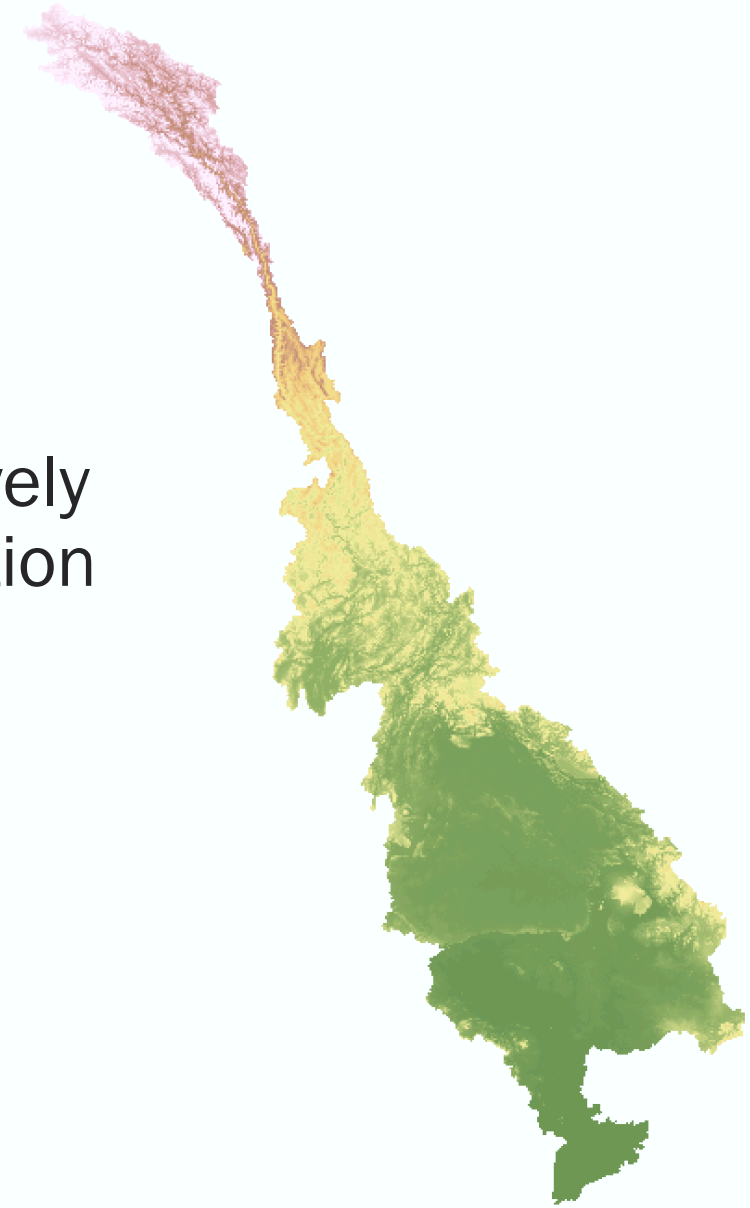
Band percent coverage

Average band elevation

- Elevation band file documentation: http://vic.readthedocs.io/en/master/Documentation/Drivers/Classic/SnowBand/

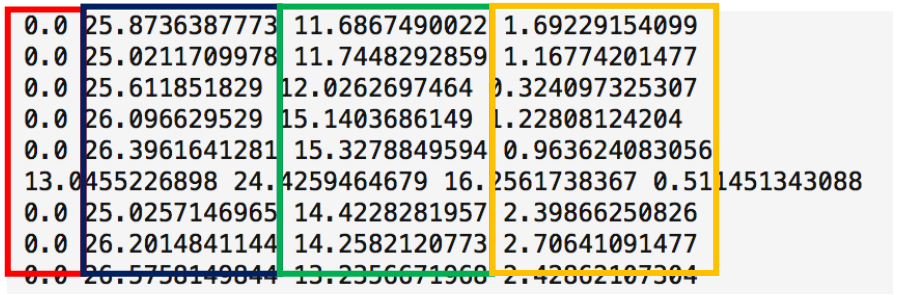
# ELEVATION DATASETS

- Plethora of DEM datasets available
  - SRTM, GMTED, HydroSheds, NED, etc.
    - http://www2.jpl.nasa.gov/srtm/
    - https://lta.cr.usgs.gov/GMTED2010
    - http://www.hydrosheds.org/
    - https://lta.cr.usgs.gov/NED
- STRM has relatively high accuracy, but also relatively high spatial resolution compared to model resolution
  - **Trade-offs between resolution and accuracy**
- Elevation data used to:
  - Create snow bands file
  - Prepare routing model inputs
  - Parameterize soils inputs



# METEOROLOGICAL FORCING

- VIC requires **four meteorological variable inputs** as a **time series for each grid cell**:
  - Daily maximum temperature (°C)
  - Daily minimum temperature (°C)
  - Surface wind speed (m/s)
  - Precipitation (mm)




Precipitation time series*

Max temperature time series

Min temperature time series

Wind speed time series

- Other meteorological inputs are supported:
  - Sub-daily temperature(°C)
  - Surface albedo (fraction)
  - Atmospheric density ($kg/m^3$)
  - Downward short and longwave radiation ($W/m^2$)
  - etc.

* Each row (space delimited) is a time step specified in the global parameter file

- Sub-daily meteorological data is needed for energy balance equations!

# METEOROLOGICAL FORCING (2 of 2)

- Meteorological forcing data is used to **drive the model processes**
- **High degree of accuracy is needed** for these datasets, otherwise model will not capture correct conditions
- Meteorological forcing input data needs to be mapped to model grid cells
  - Need to interpolate station data
- Global datasets
  - Temperature
    - ERA-Interim, http://www.ecmwf.int/en/research/climate-reanalysis/era-interim
    - MERRA-2, https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/
    - CSFR, https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2#CFS
    - Princeton dataset, http://hydrology.princeton.edu/data.pgf.php
    - Reanalysis
  - Precipitation
    - Next slide…

# METEOROLOGICAL FORCING (1 of 2)

- Global datasets (continued)
  - Precipitation:
    - CHIRPS, http://chg.geog.ucsb.edu/data/chirps/
    - IMERG, https://disc.gsfc.nasa.gov/datareleases/imerg_data_release
    - CMORPH, http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html
    - GPCC, https://www.esrl.noaa.gov/psd/data/gridded/data.gpcc.html
    - Reanalysis
  - Wind: Reanalysis
  - Station data:
    - GSOD, https://data.noaa.gov/dataset/global-surface-summary-of-the-day-gsod
    - GHCN, https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn
  - Typically lack spatial resolution but have required variables and temporal resolution

# VIC MODELING OPTIONS

- VIC supports a wide variety of modeling applications
  - Open source nature of model development
  - You can contribute!
- Can specify which model modes/components you would like to use for your own applications
  - For example: Water balance mode vs full energy balance mode
  - Most often needs additional data inputs

Example: http://hydro.washington.edu/forecast/monitor_west/

# SPATIAL DISTRIBUTION OF PRECIPITATION

- Distributes precipitation throughout grid cell as a function of rain intensity
  - Can account for orographic effects with small scale precipitation
  - Parameterize using climatology
- Fractional coverage is based on exponential relationship
- Soil moisture is averaged for grid cell before a new storm occurs
- Spatially distributing rain is parameterized within the snow bands file

# FROZEN SOIL SIMULATIONS

- Important component in cold regions (high elevations or high latitudes)
- Frozen soils can impede the infiltration of water content
- Can alter spring soil moisture content and timing of streamflow
- Has impact of the energy balance
  - Energy balance is solved at each node within the soil and iterated for convergence

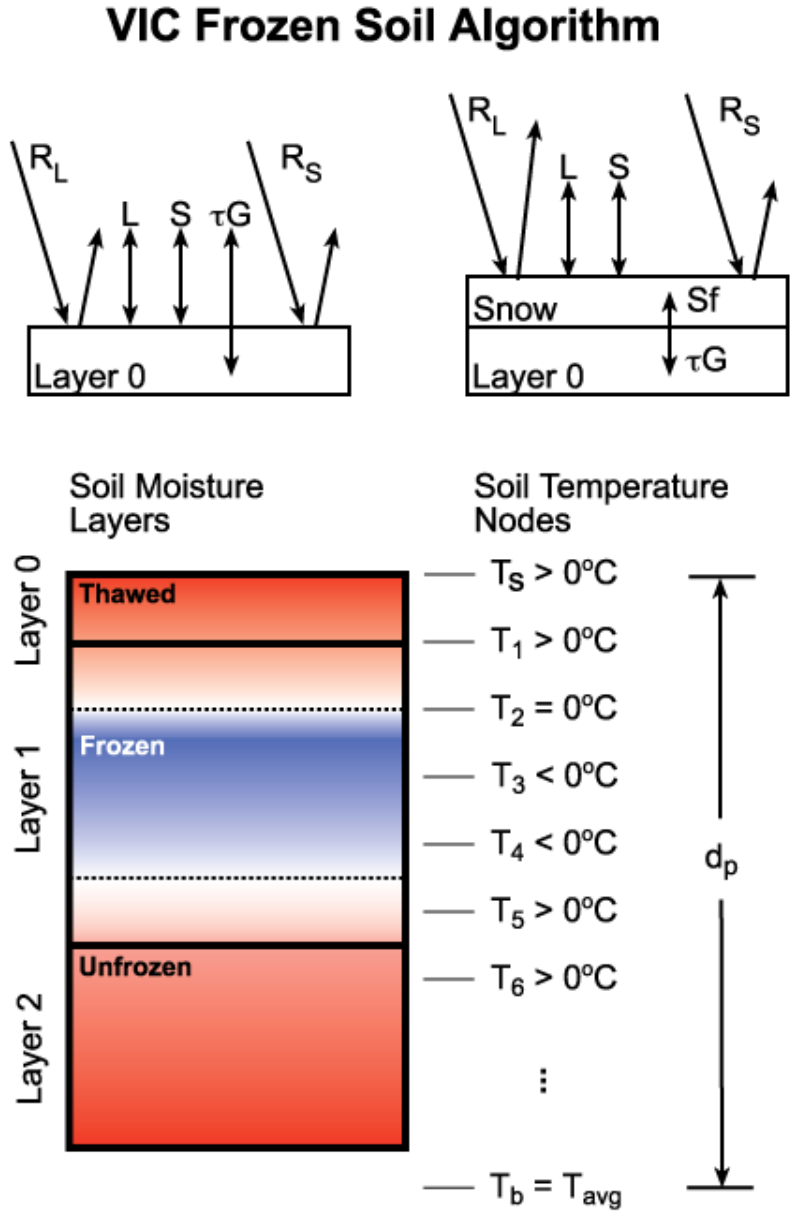



Image from Open Access VIC Documentation:
http://vic.readthedocs.io/en/master/Overview/ModelOverview/

# LAKE AND WETLAND MODEL

- Solves lake energy balance at different layers
  - Incorporates lake ice coverage, more realistic representation of surface processed over lakes
  - Takes into account water in/outflow
  - Assumes ”one” lake per grid cell
- Wetland model allows for season inundation of wetlands
  - Better models the inter-annual water balance for wetland areas
  - Channel/soil recharge depending on flux demand

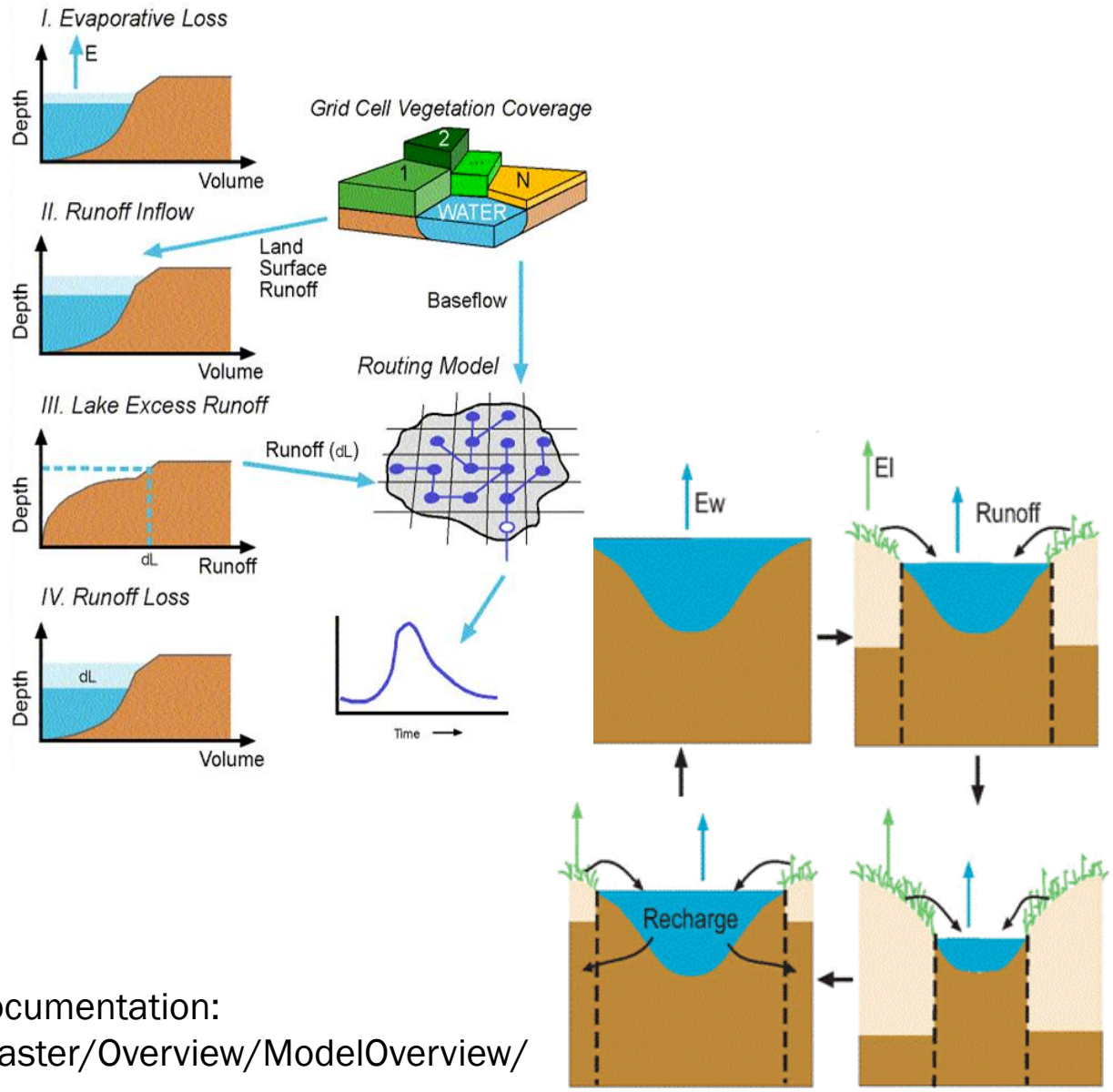


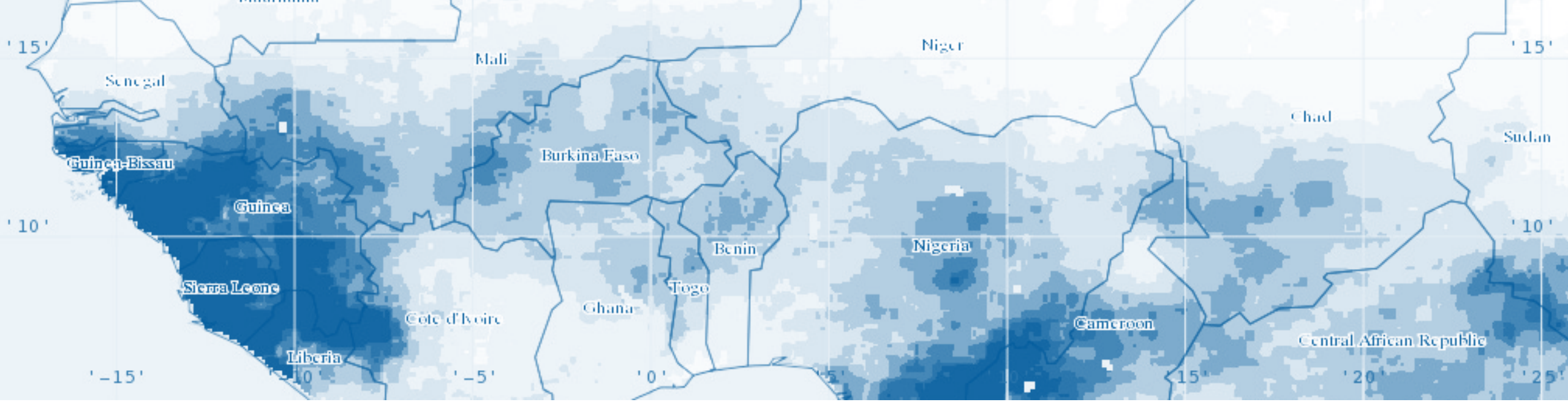

Image from Open Access VIC Documentation:
http://vic.readthedocs.io/en/master/Overview/ModelOverview/

# CARBON CYCLE MODEL

- Allows for the simulation of vegetation photosynthesis and respiration
- Plant phenology is not dynamic
  - Based on land surface parameterization (monthly LAI climatology)
- Vegetative biomass is not simulated
  - Total carbon storage in plants
- Calculates yearly Net Primary Productivity (NPP) based on vegetation type and meteorological conditions

# HYDROLOGIC STATE FILES

- Users can save last model conditions (specifically soil moisture conditions) to file
- Important if using the model for hydrologic forecasts
  - Minimum model spin-up time is 1 year
- Saves computation time
- Model outputs are not consistent when using state files
  - Small differences in soil moisture results between using and not using a state file




# THANK YOU

Kel Markert

kel.markert@nasa.gov

VIC/BCSPP Training

Huntsville, AL