Drought Monitoring in Data Sparse Regions

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Drought Monitoring Workshop
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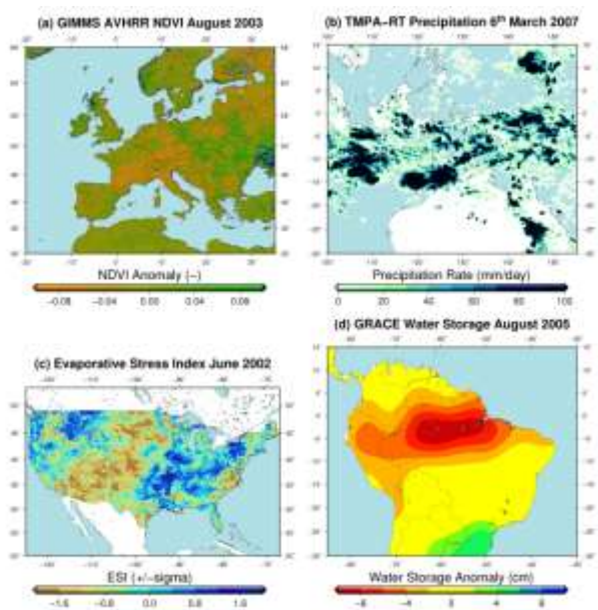
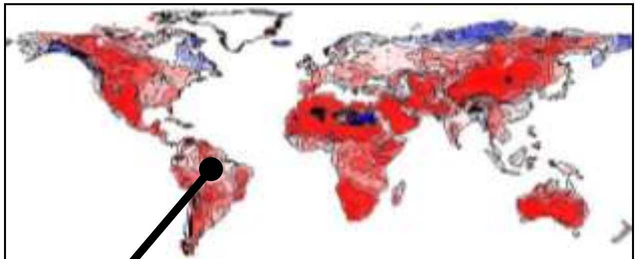
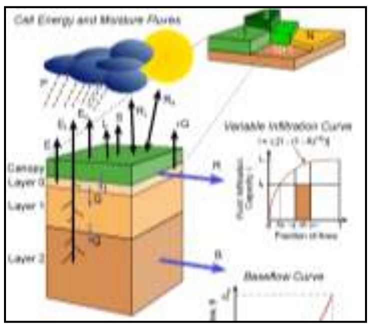


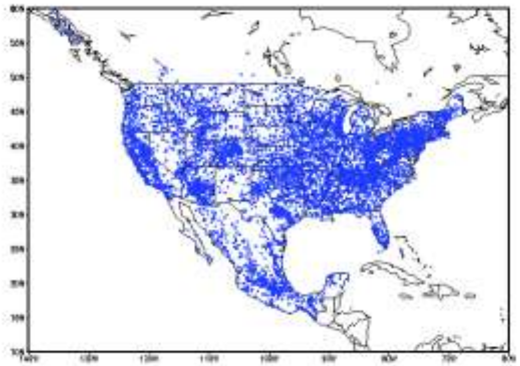
Data and Tools for Drought Monitoring and Prediction



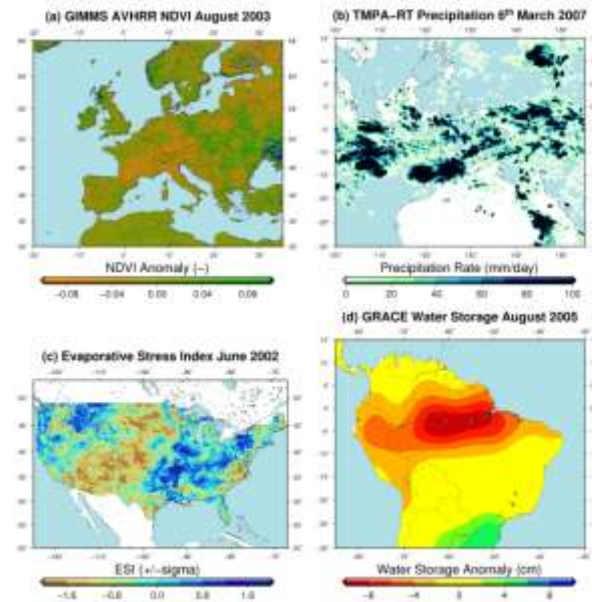
Hydrological Modeling



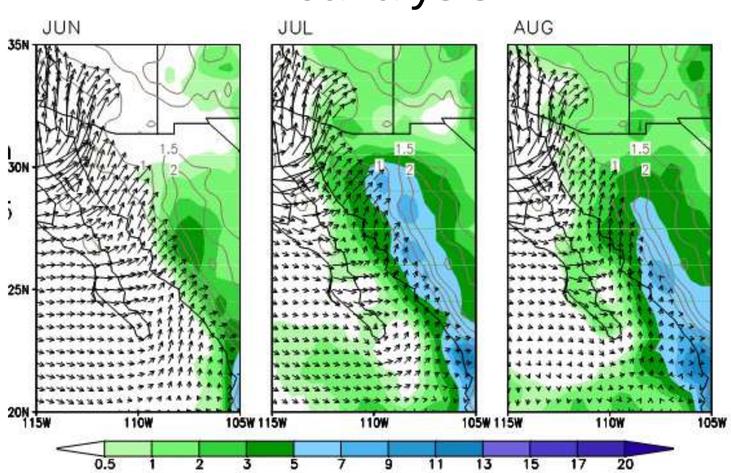
Ground Observations



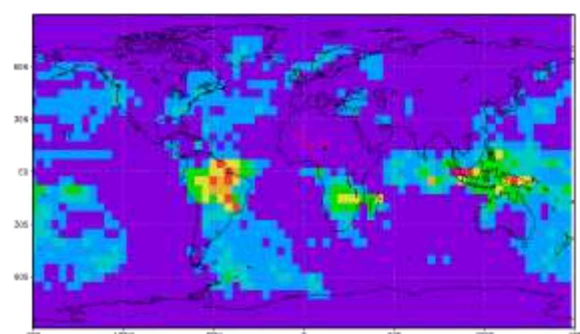
Satellite Remote Sensing



Reanalysis

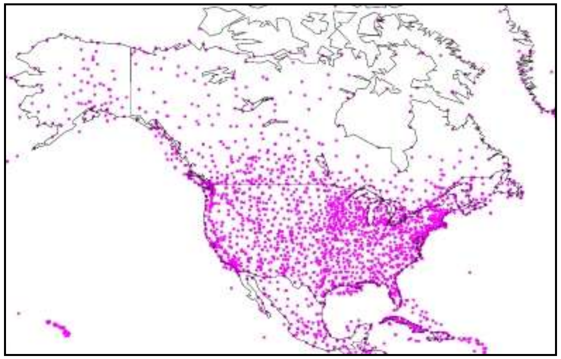


Regional/Global Climate Models, Statistical Prediction



Observing the Water Cycle: Ground Measurements

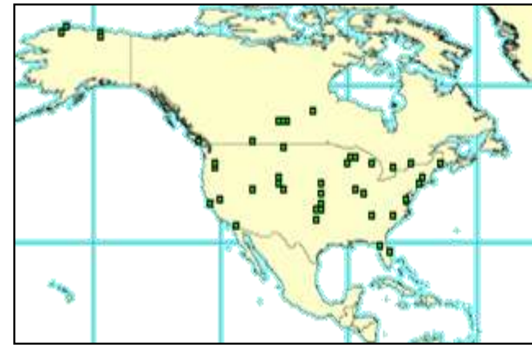
Precipitation - the best measured

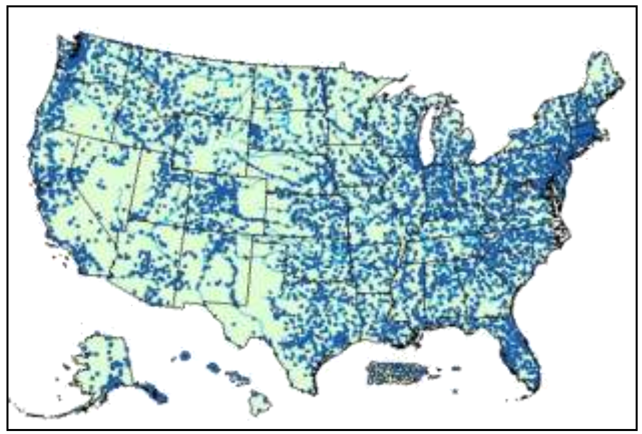


U.S. station density: 1 per 700 km^2

Ameriflux (flux towers) measure E, since mid 1990's

$$Q = P - E - dW/dt$$

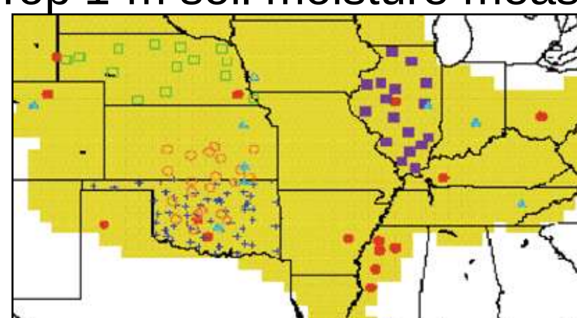




Streamflow measured at roughly 7,000 active gauging stations.

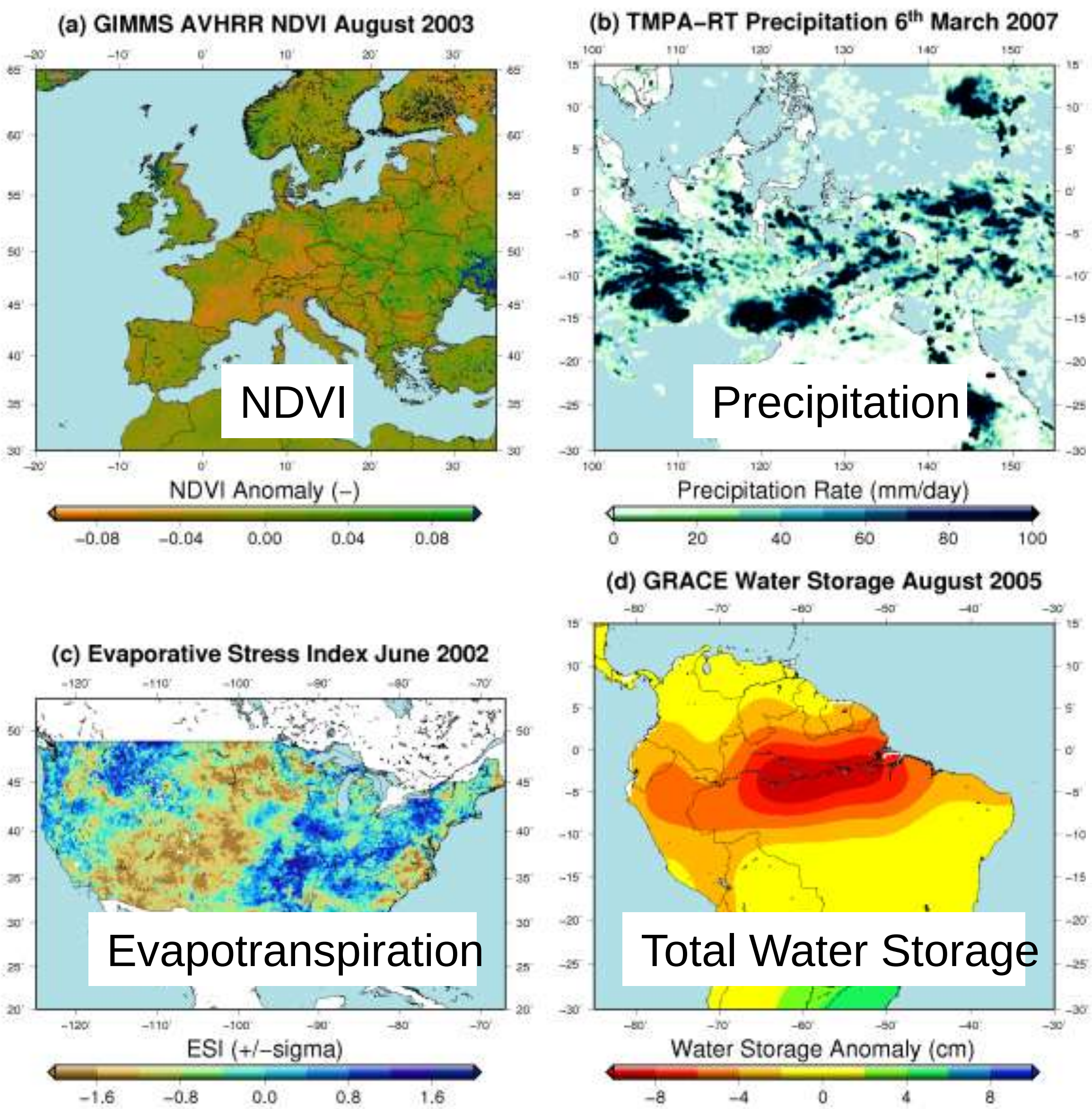
Snow water equivalent at SNOTEL sites

Top 1-m soil moisture measurements

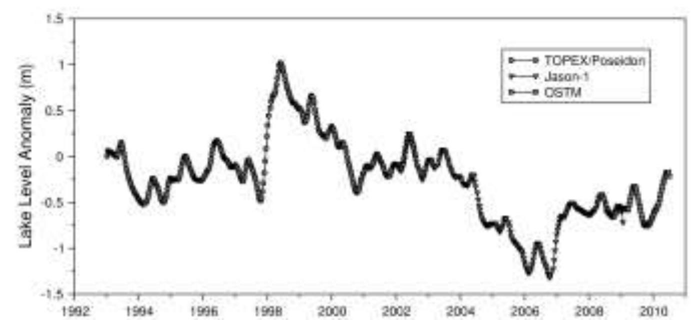


Source: *A. Robock, Rutgers U.*

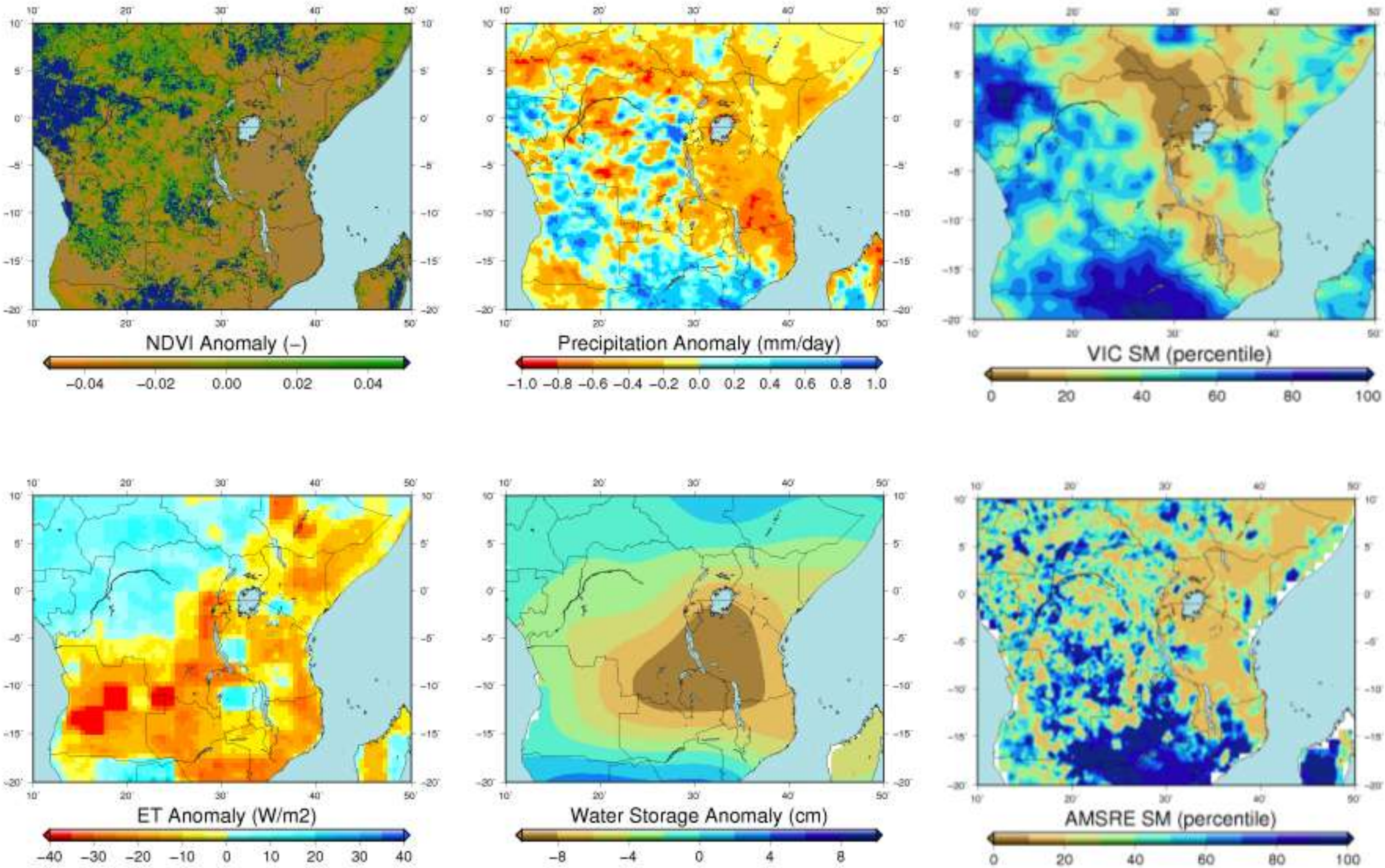
Observing the Water Cycle: Remote Sensing



Satellite Altimetry of Large Water Bodies

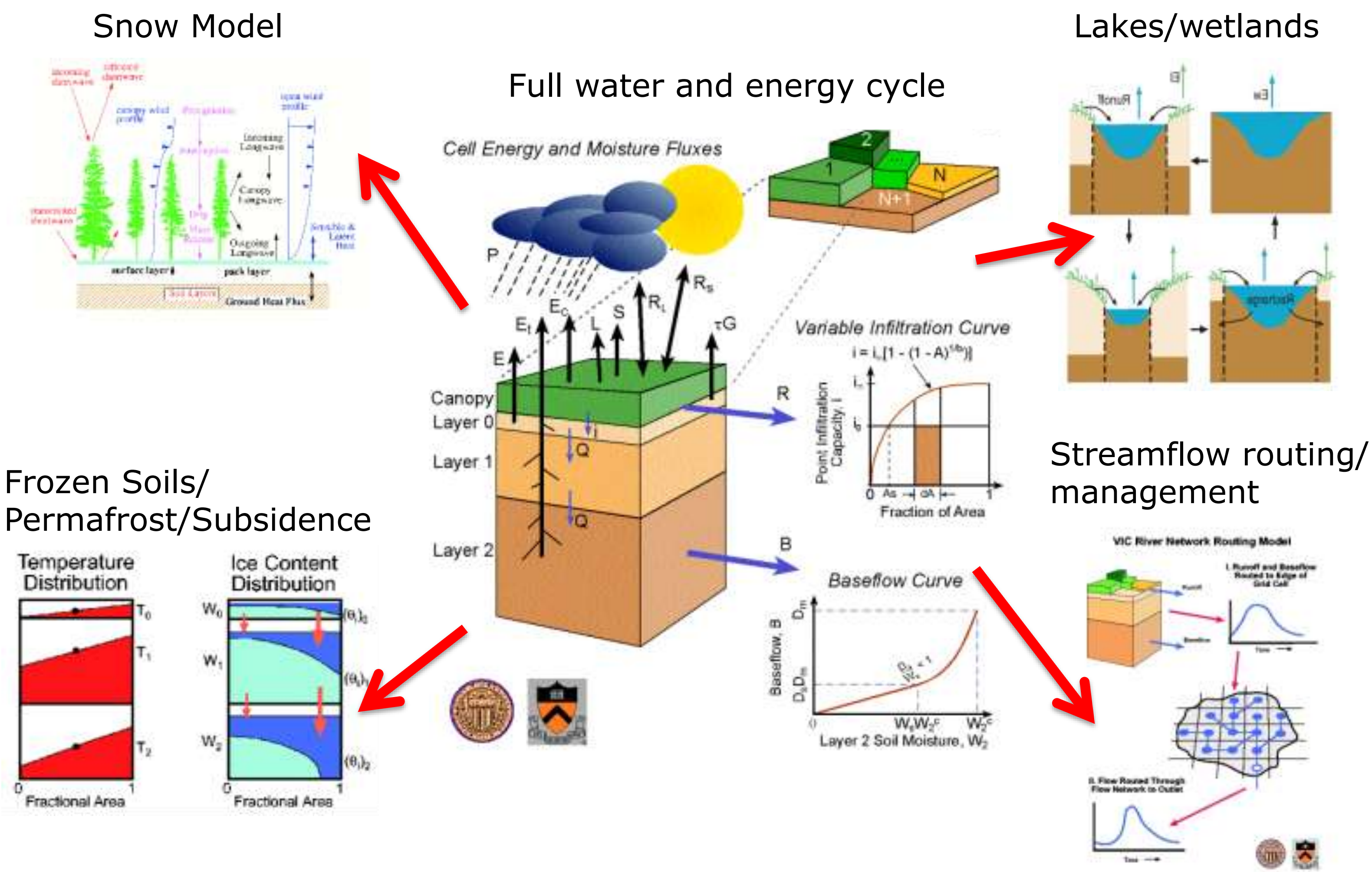


Multi-Sensor View of a Single Drought Event



Observing the Water Cycle: Modeling

VIC Land Surface Hydrologic Model



Use of Models to Provide Continuous and Consistent Data

Observational/ Modeled Data

- Precipitation
- Meteorology
- Vegetation
- Soils

Modeling and Assimilation

Land Surface Hydrology Model (VIC)

Remote Sensing and In-Situ Data
GRACE, ET, SM, Snow, Altimetry, Streamflow

Applications

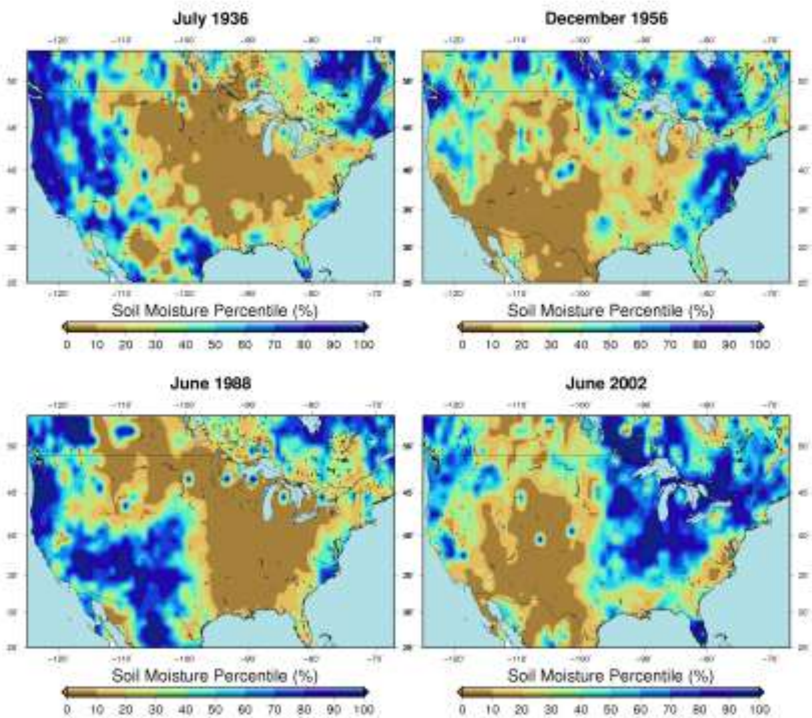
- Land Use Change
- Hydrologic Prediction
- Water Resources
- Agricultural Management
- Wildfire Forecast
- ...

Drought Analysis

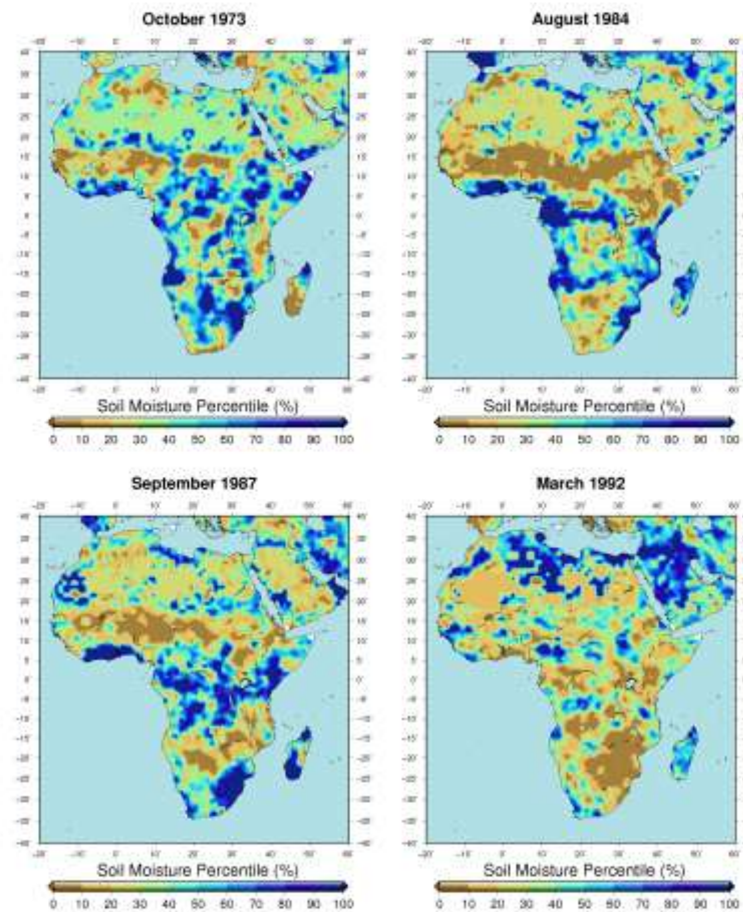
• Contributes to quantifying current conditions against history
• Contributes to seasonal prediction through understanding Drought Mechanisms

Selected Major Regional Drought Events

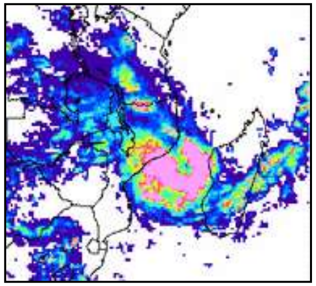
USA



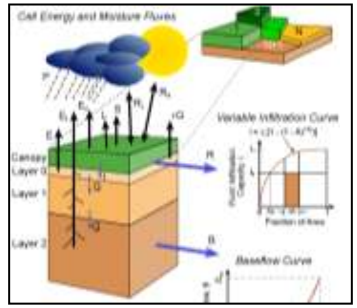
Africa

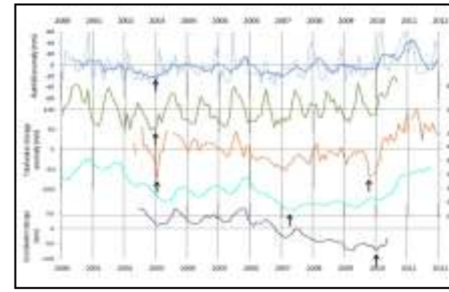


Putting it all together:
Hydrological and Drought Monitoring System



Real-time Weather

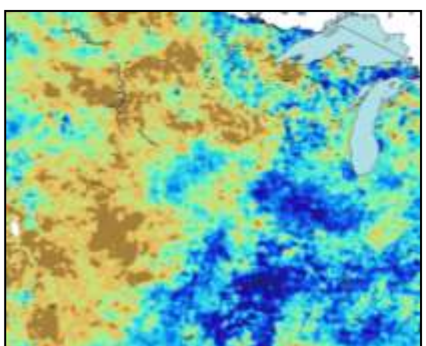




Land surface (hydrology) models

Hydrological Variables, Streamflow, Drought Indices

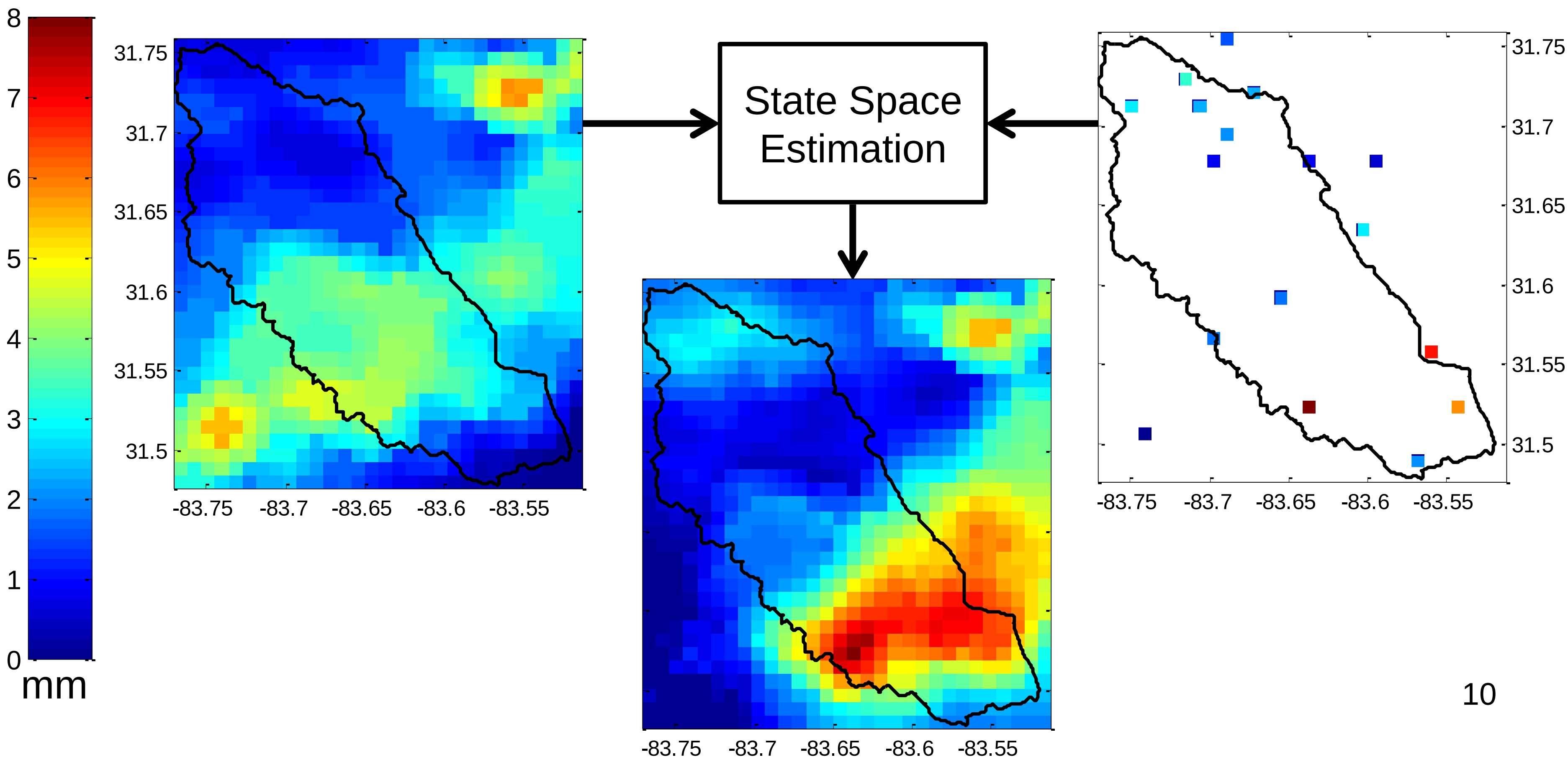
Initial Conditions



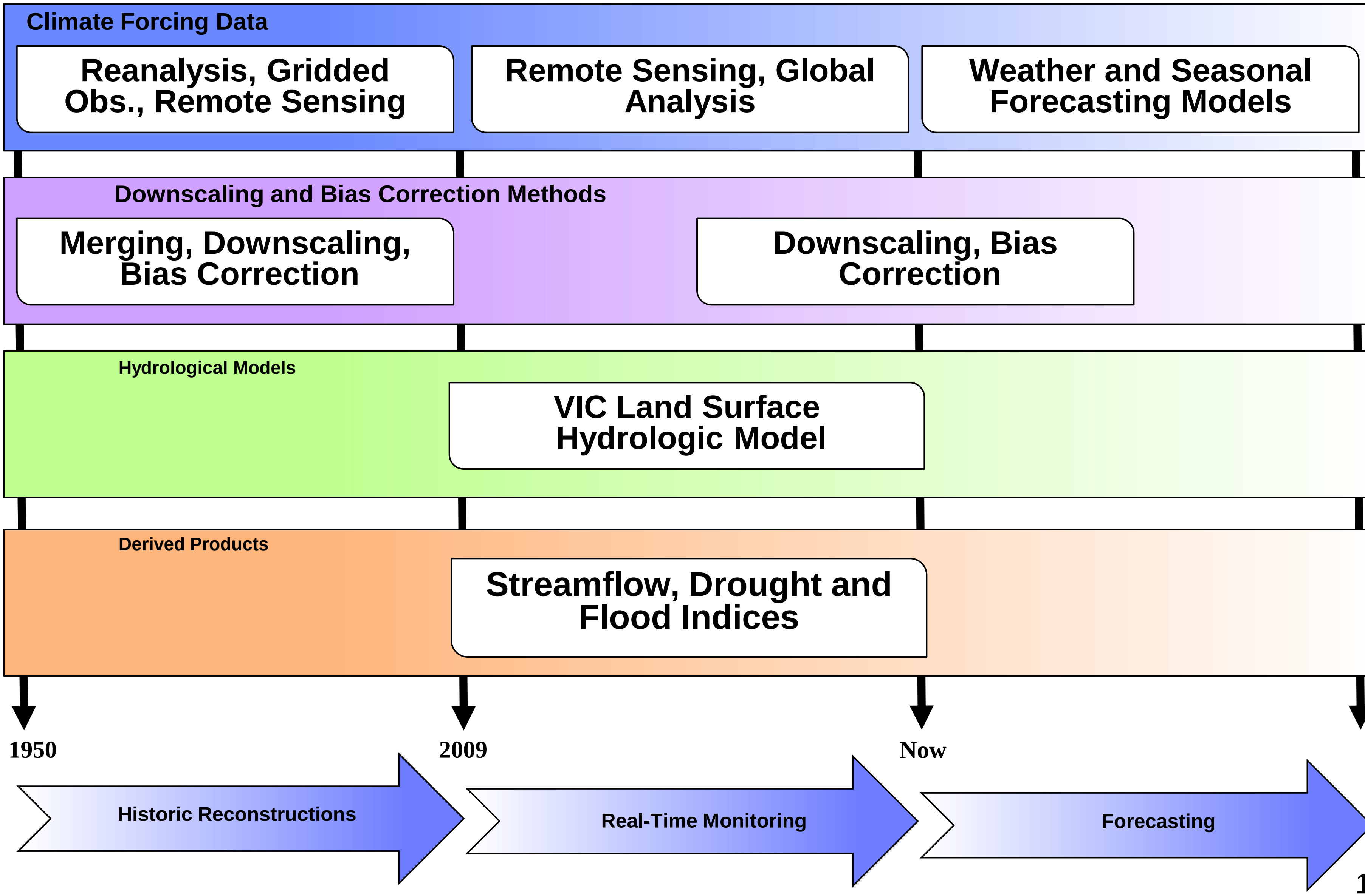
Management/Mitigation

Some Challenges of Large Scale Monitoring

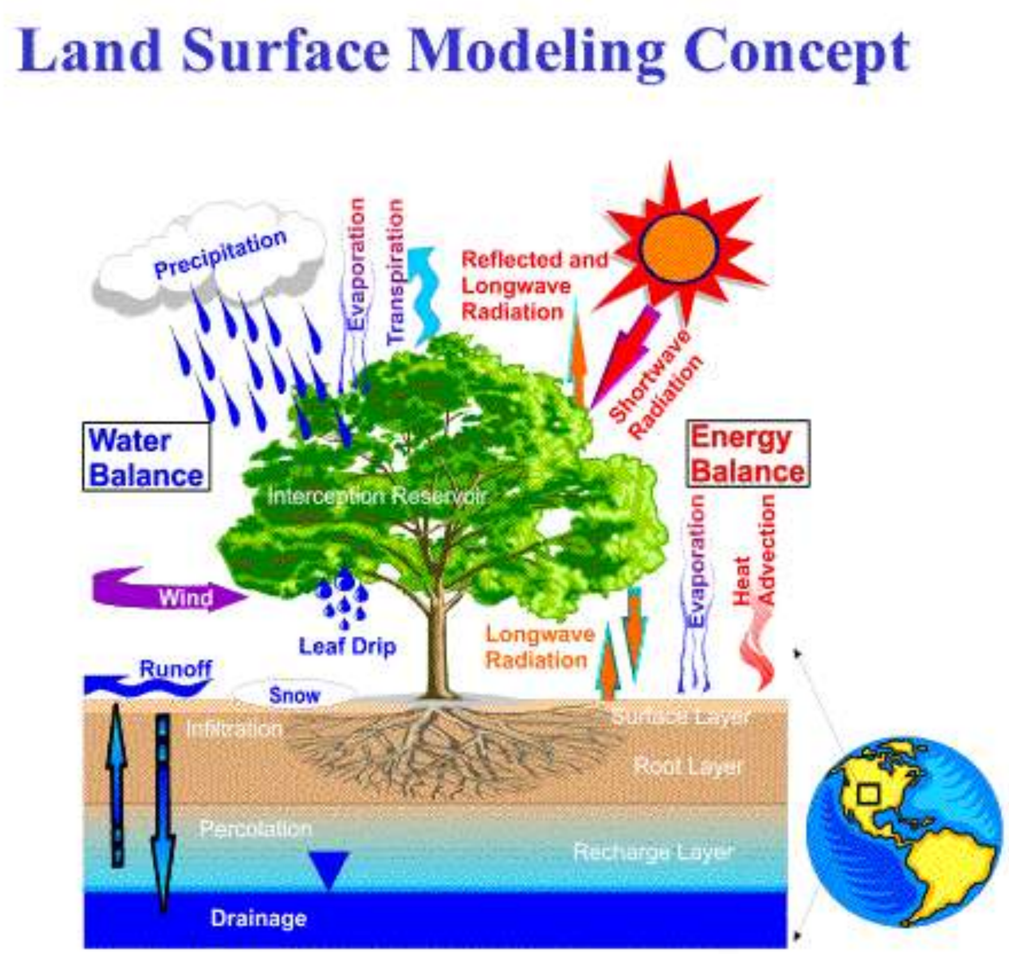
- Validation of remote sensing products, hydrological modeling, drought products
- Assimilation of local measurements (gauge data for precipitation, streamflow, etc)



Introduction to the Flood and Drought Monitor



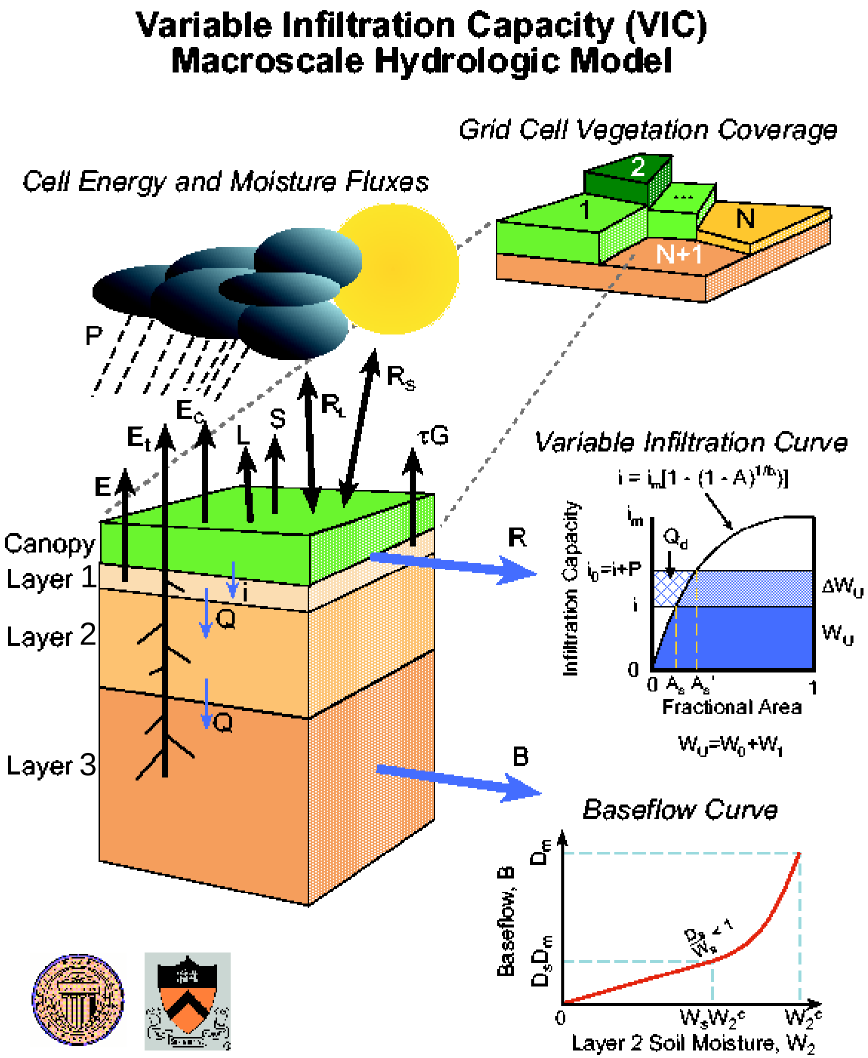
Land Surface Model: Land – Atmosphere Interaction



- <u>Model the interaction between the land and atmosphere.</u>
- Processes to account for:
  - **Water balance**
    - $\Delta S = P - E - R$
  - **Energy balance**
    - $SW\downarrow + LW\downarrow - LW\uparrow - SH - LH - G = 0$

- <u>Terminology</u>
- ΔS = Change in storage
- P = Precipitation
- E = Evapotranspiration
- R = Runoff
- $LW\uparrow$ = Upward Longwave Radiation
- $LW\downarrow$ = Downward Longwave Radiation
- $SW\downarrow$ = Downward Shortwave Radiation
- α = Surface Albedo
- LH = Latent Heat
- SH = Sensible Heat

Land Surface Model: Variable Infiltration Capacity



1. Each grid cell is modeled independently without horizontal flow.
2. The surface of each grid cell is described by *N+1* land cover tiles.

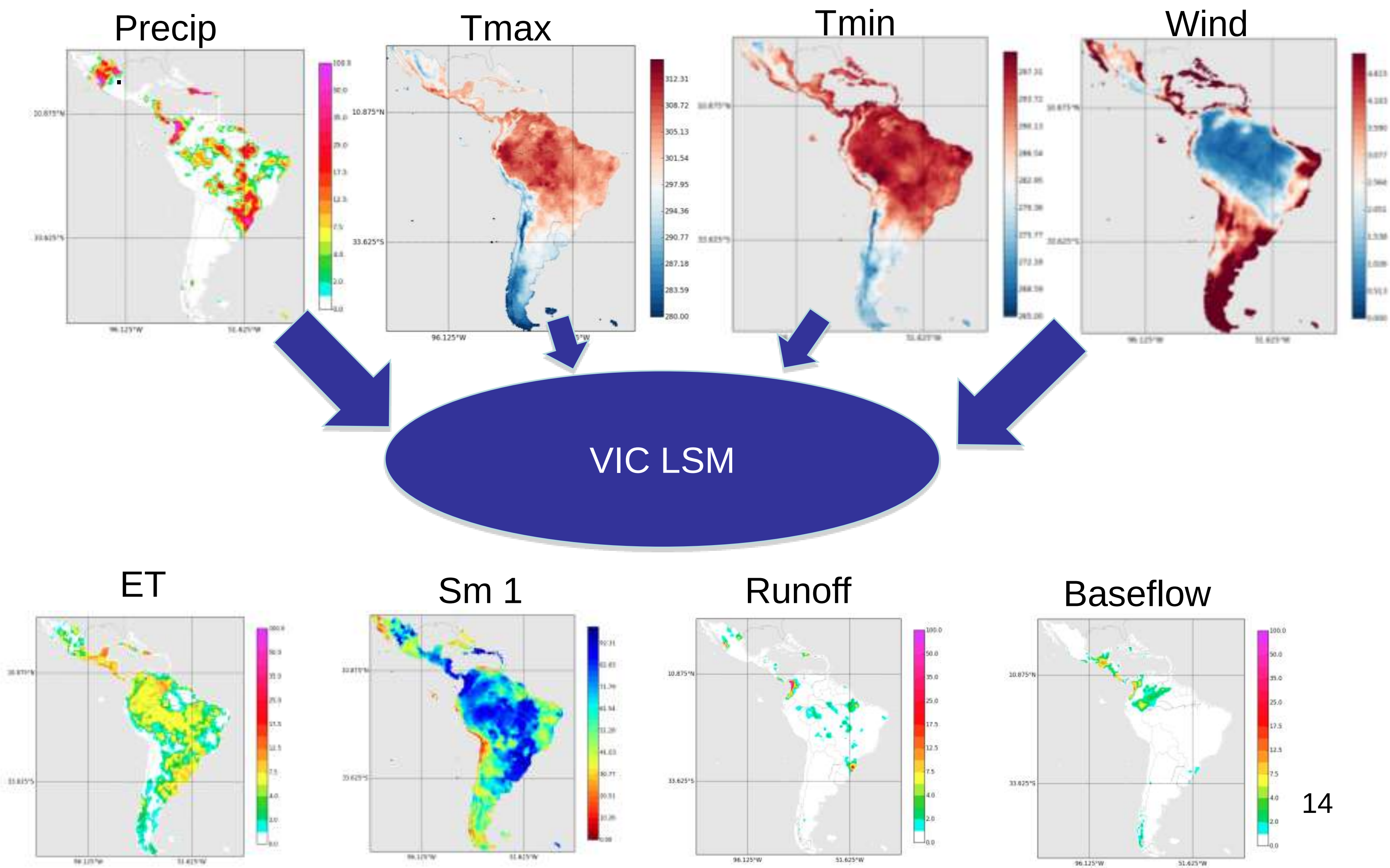
3. Evapotranspiration is calculated for all vegetation tiles in a grid cell and then averaged over the grid cell.

4. The top two soil layers are designed to represent the dynamic response of soil.
5. Baseflow comes from the layer 3.

6. The variable infiltration curve parameterizes the spatial variability of infiltration.

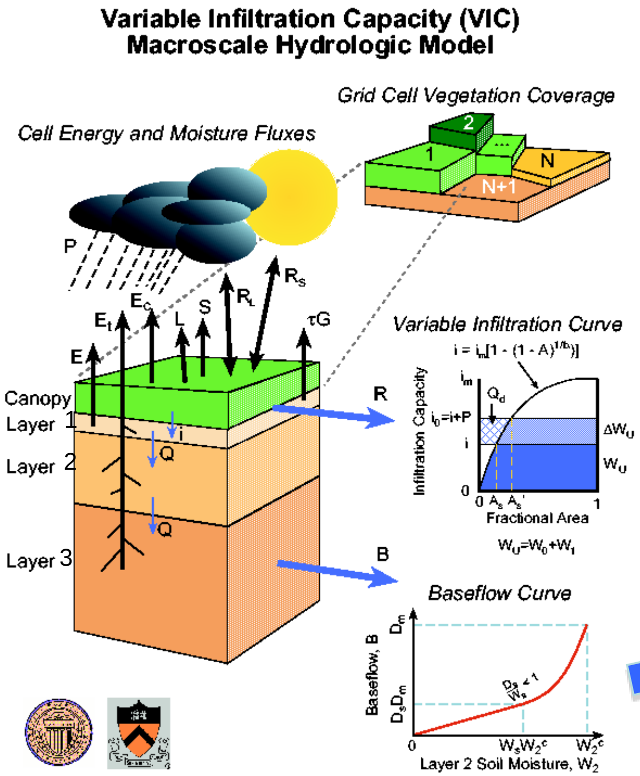
Land Surface Model: Example

Land Surface Model Setup:

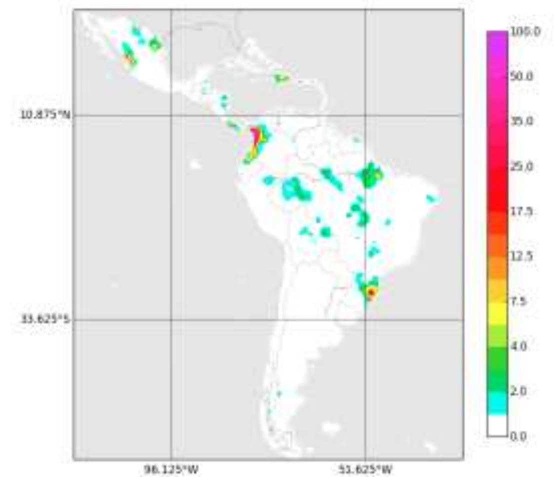


Land Surface Model: Simulate Discharge

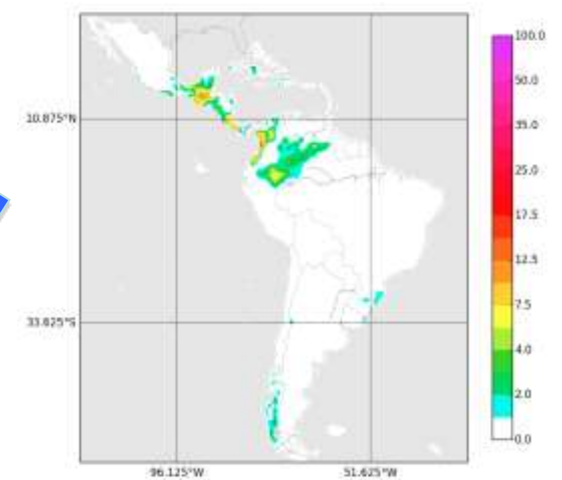
- How do we simulate discharge at stream gauges using our land surface model output of baseflow and surface runoff?



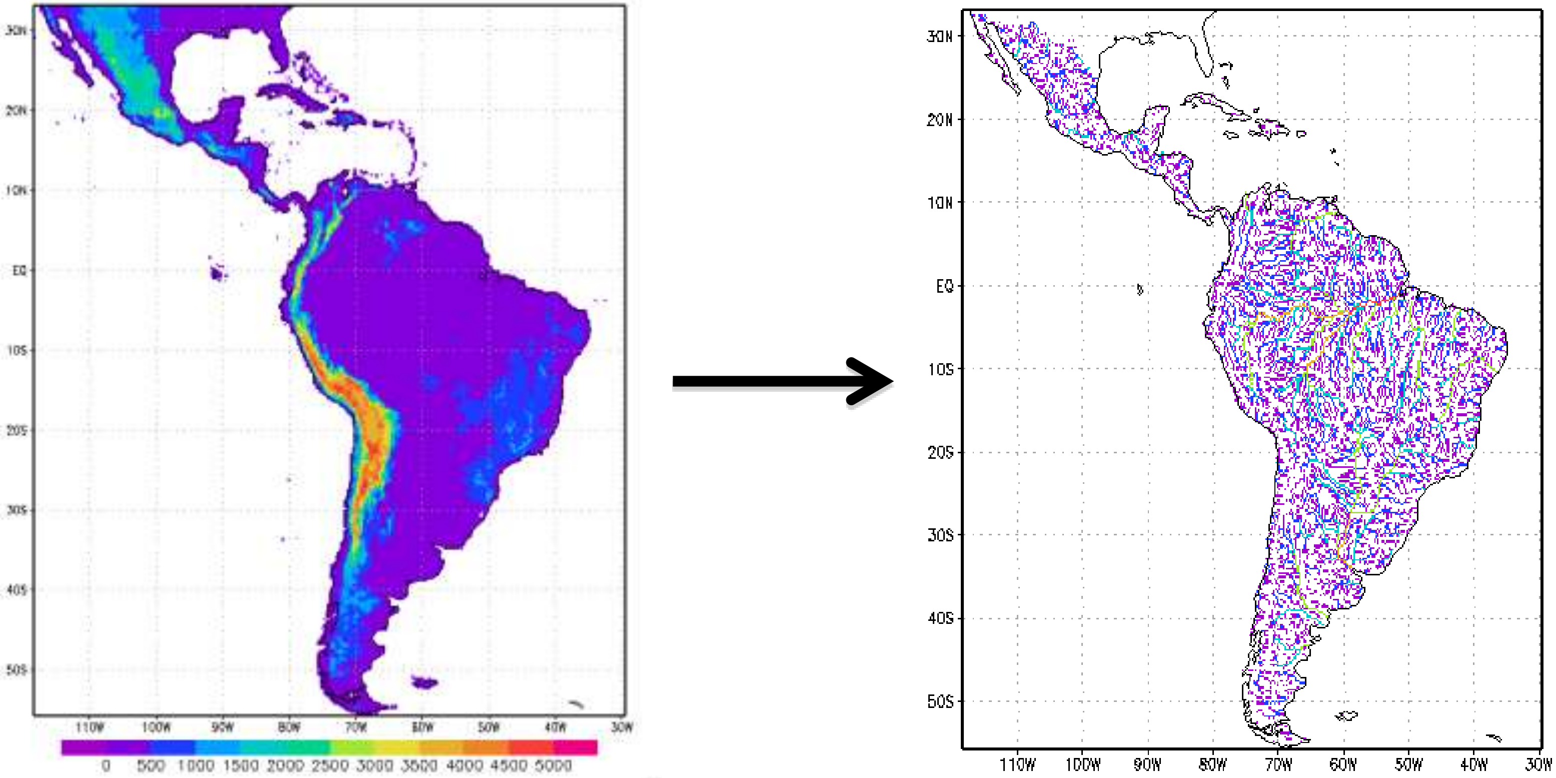
Runoff



Baseflow



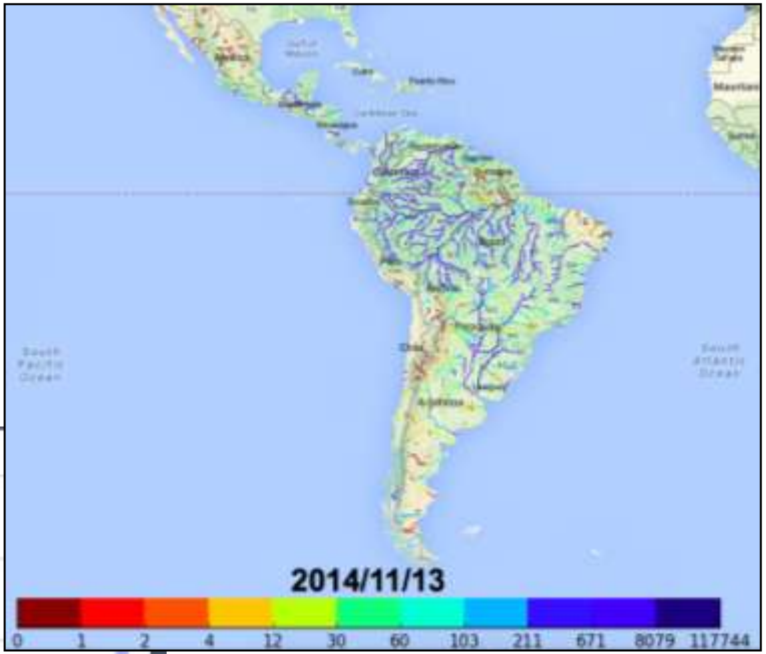
Simulate Discharge

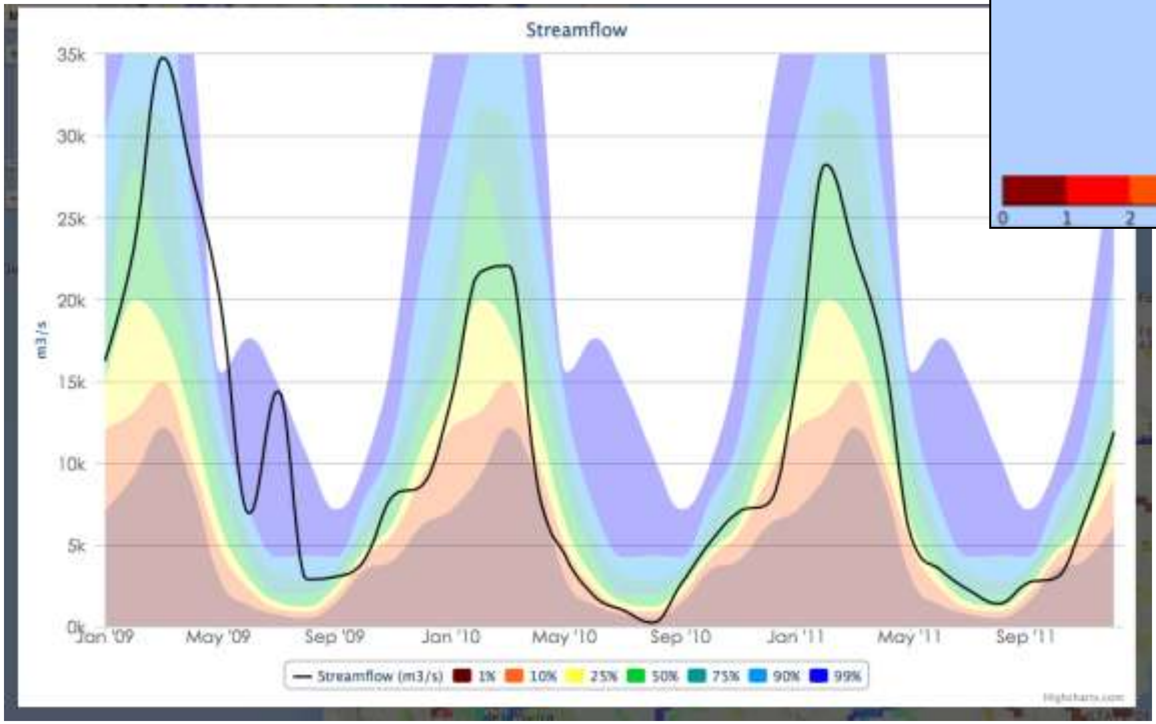


- Use the elevation data to delineate the basins (Hydrosheds).
- Determine the path that surface runoff and baseflow from each grid cell follow until reaching the stream gauge.
- For each grid we essentially add up the contributions at that time step from all grid cells.

Simulate Discharge: Routing Model

Ultimately, we produce gridded estimates of discharge that can easily be viewed as time series for a single grid

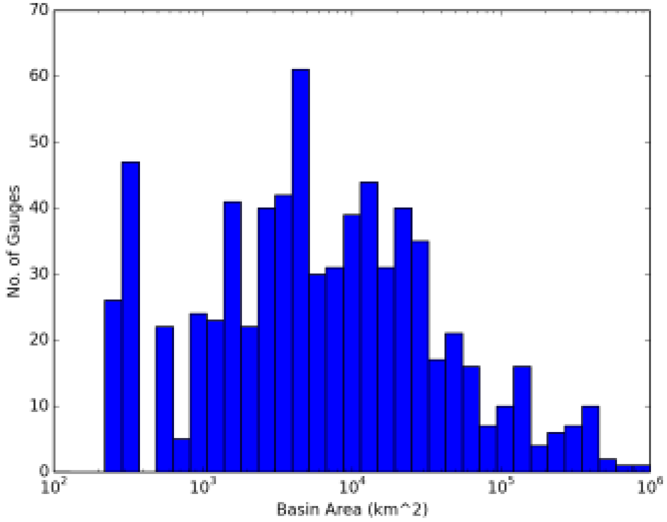




Validation: Grid Cell Runoff Observations

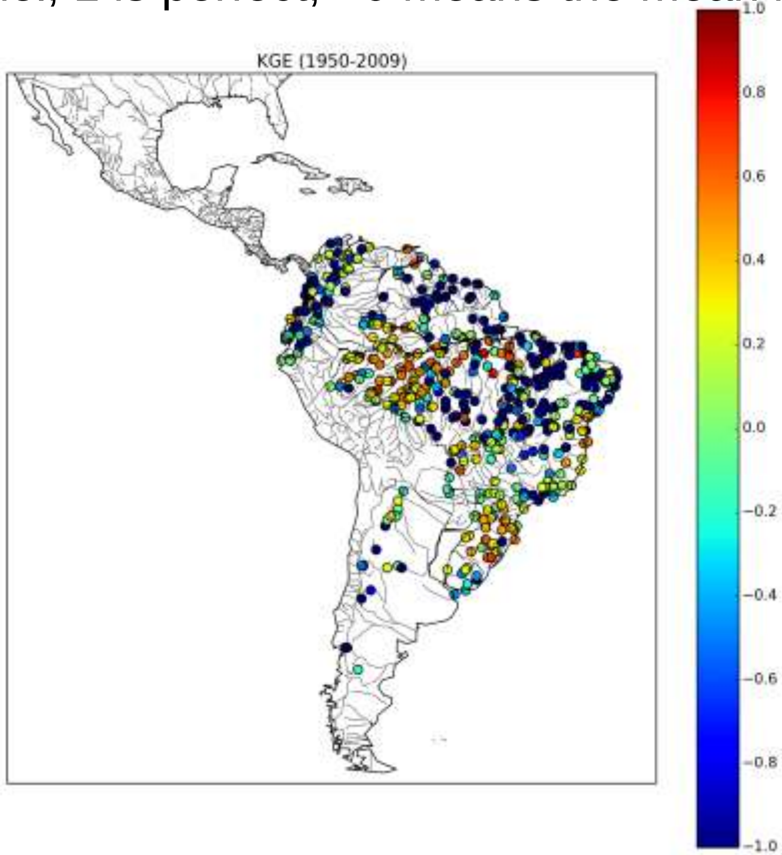
Validate the model against discharge observations

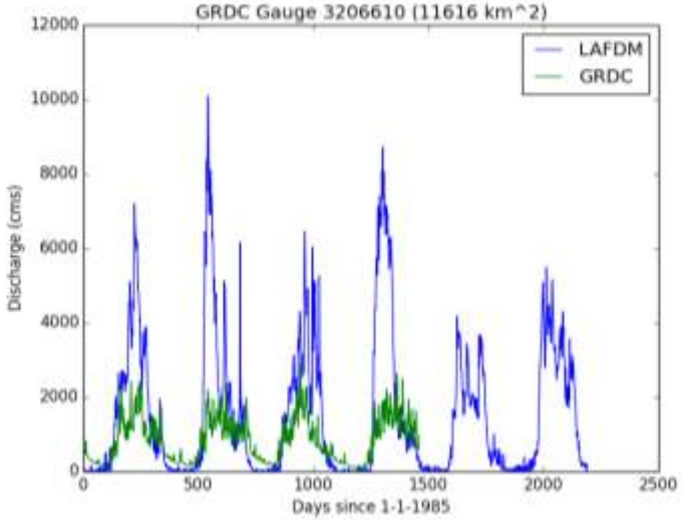
- GRDC (Global Runoff Data Center) database (1950 – 2010)
  - The points represent stream gauges.
  - Each stream gauge has a corresponding catchment.
  - Data is available in both monthly and daily forms

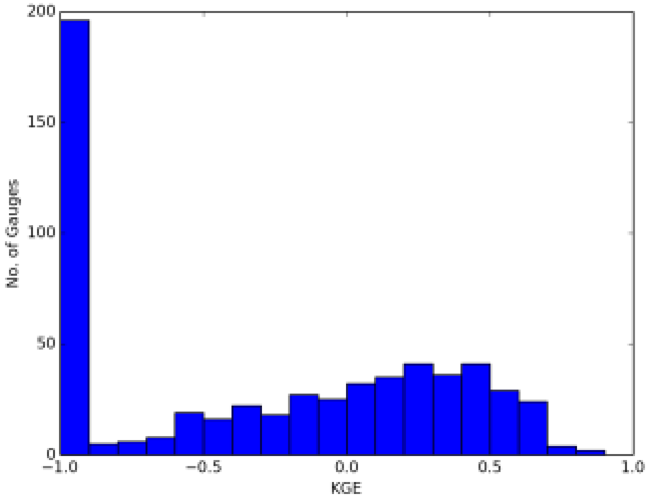


Validation of the Land Surface Model

Kling-Gupta Efficiency:
Measure of the correlation, bias and variability of model, 1 is perfect, <0 means the mean is better

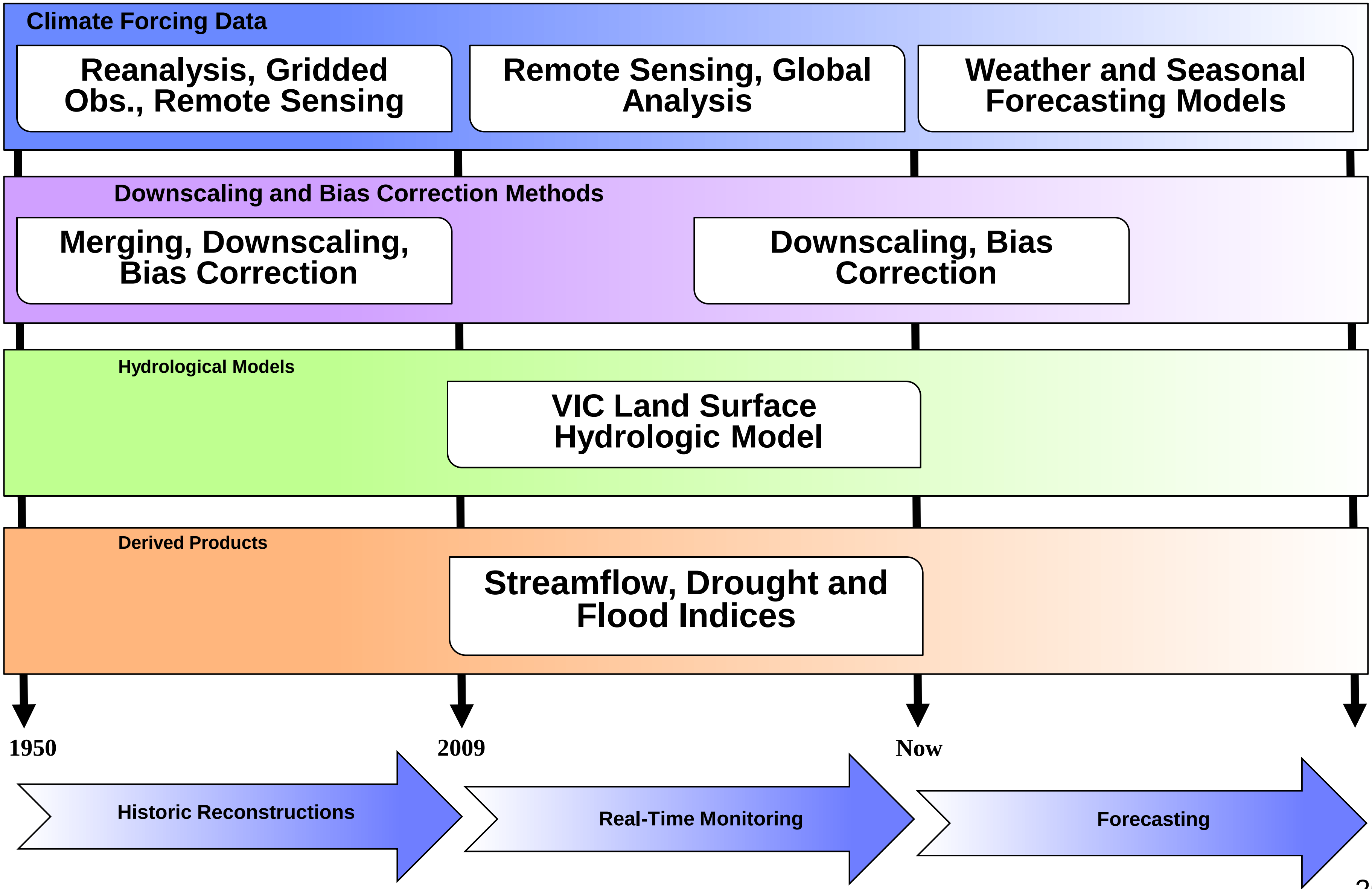






Future calibration may improve the land surface model's ability to reproduce measured discharge. Additional gauges will also be useful.

Part 2: Meteorological Data

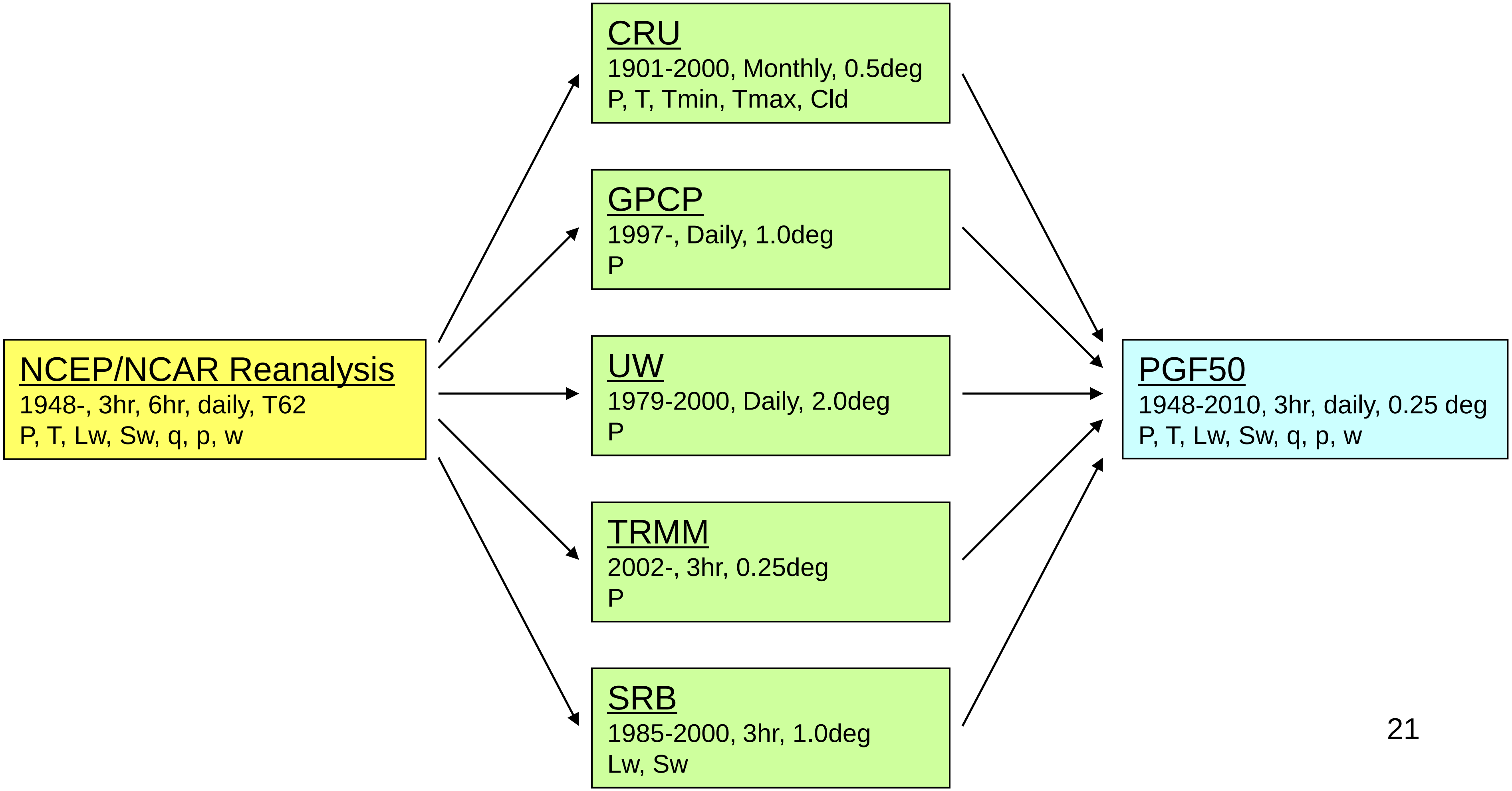


Historical Meteorological Dataset

Reanalysis
High temporal/low spatial resolution
MANY BIASES and SPURIOUS TRENDS

Observations
Generally low temporal/high spatial resolution
BEST ESTIMATE of individual variables

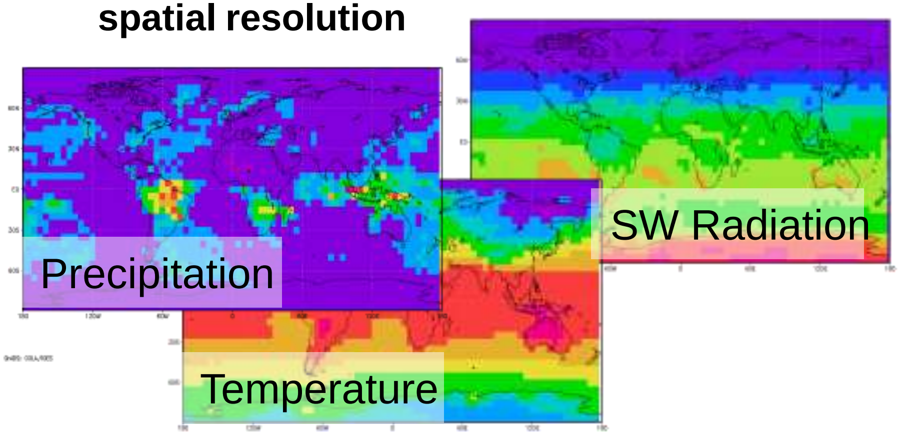
Forcing Dataset
High temporal/high spatial resolution:
CORRECTED, CONSISTENT



Historical Meteorological Dataset

Reanalysis

High temporal/low spatial resolution



Observations

Generally low temporal/high spatial resolution

CRU
190
P, T

GPCP
199
P

UW
197
P

TRMM
200
P

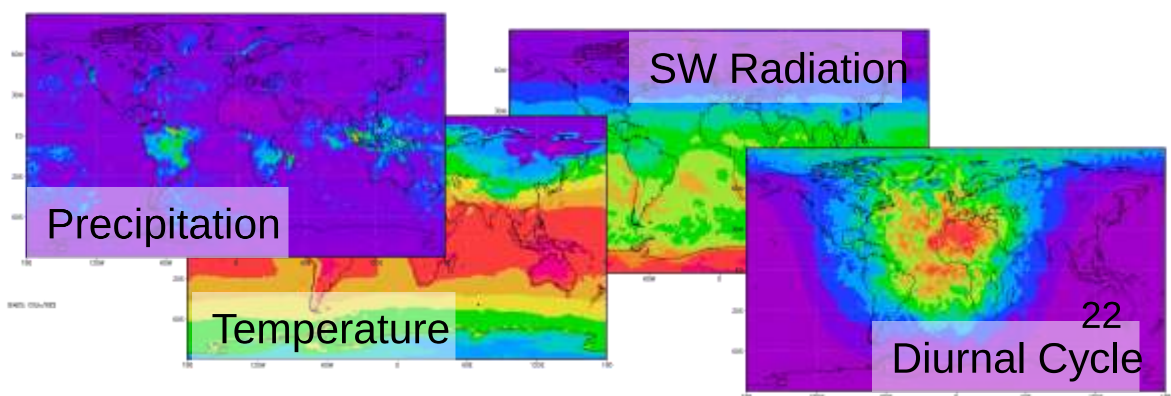
SRB
1985-2000, 3hr, 1.0deg
Lw, Sw

Bias Correct and Downscale

- corrected rainday statistics, gauge undercatch
- removal of biases in monthly P, T, DTR, SW, LW
- removal of spurious trends in SW
- adjustment for elevation effects
- downscale in time and space

Global Forcing Dataset

High temporal/high spatial resolution, bias corrected, trend corrected, etc…

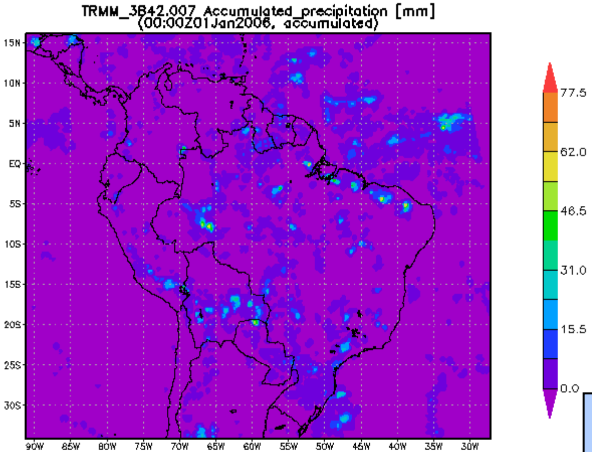


Real-Time Meteorological Data: Precipitation Data

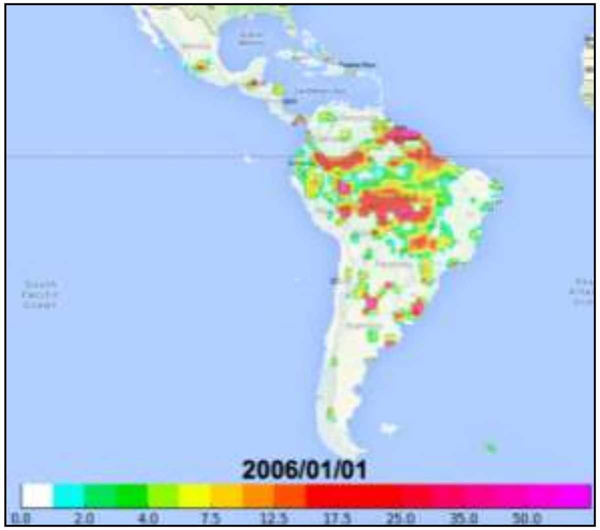
Satellite Precipitation

Monitor uses TRMM 3B42v7 daily precipitation estimates, bias corrected against the historical climatology

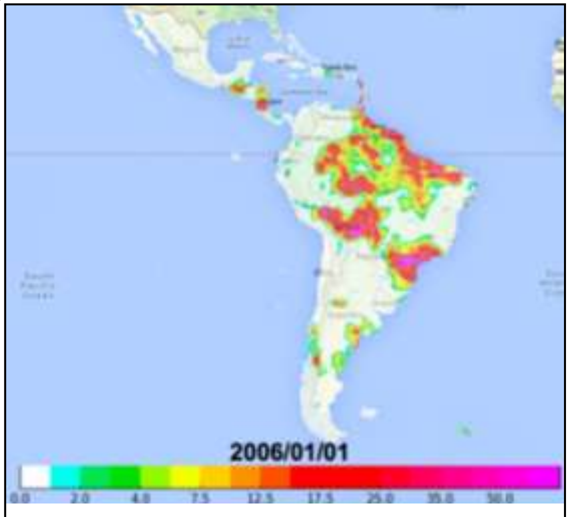
TRMM



PGF

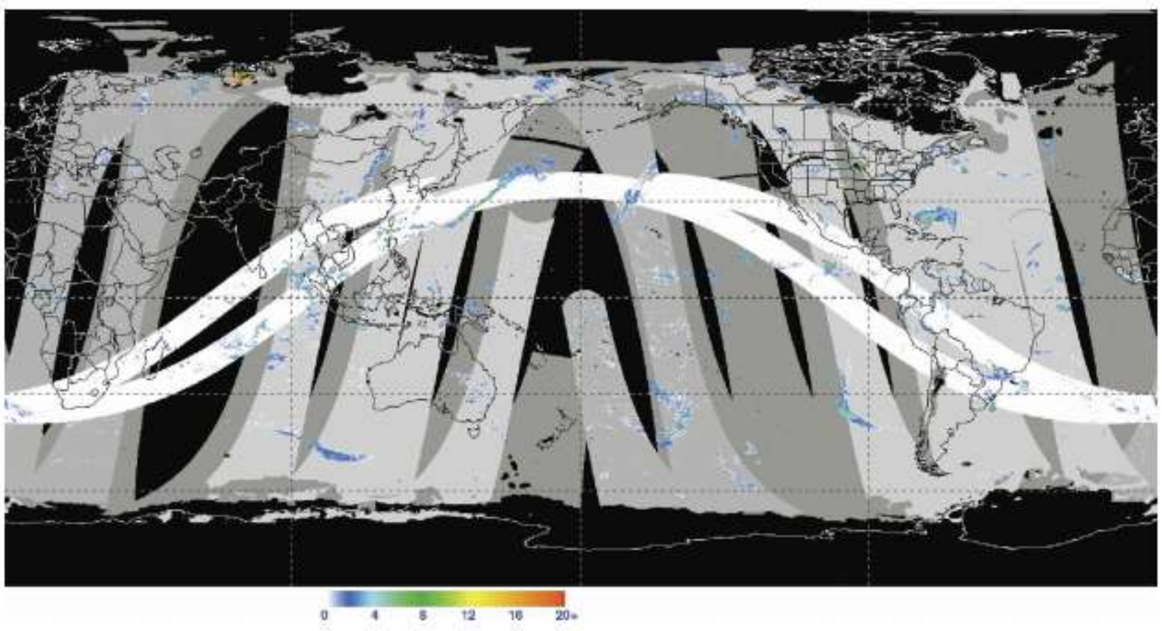


Bias Corrected



Satellite Precipitation - TMPA (Example)

TMPA – TRMM Multi-Satellite Precipitation Analysis



3-hour period centered at 0000 UTC 25 May 2004
- Different Sources:
  - TMI (white)
  - SSM/I (light gray)
  - AMSR-E (medium gray)
  - AMSU-B (dark grey)

A diverse, growing set of input precipitation estimates – various
- periods of record
- regions of coverage
- sensor-specific strengths and limitations

Real-Time Meteorological Data: Weather Model

Global Forecast System

1. Global weather forecasting model at 1 degree spatial resolution
2. Run by NOAA (National Oceanic and Atmospheric Administration) in the United States.
3. Run every 6 hours at 00,06,12,18 hours UTC.

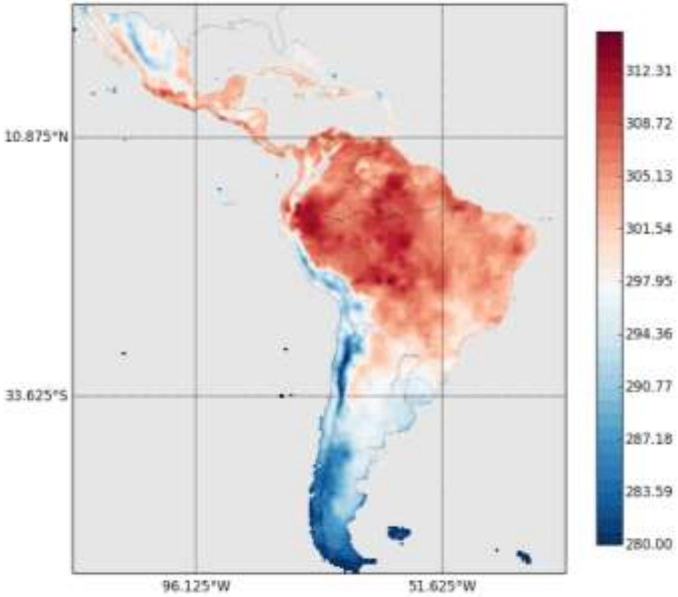
- Initial conditions are necessary at the beginning of each forecast.
  - The Initial conditions come from GDAS (Global data assimilation system)
- The observation based initial-conditions are used to find temperature and wind speed data.
- Forecasts of precipitation are used to supplement TRMM observations
- **<u>Used in the drought monitor since 2009.</u>**

Real-Time Meteorological Data: Weather Model

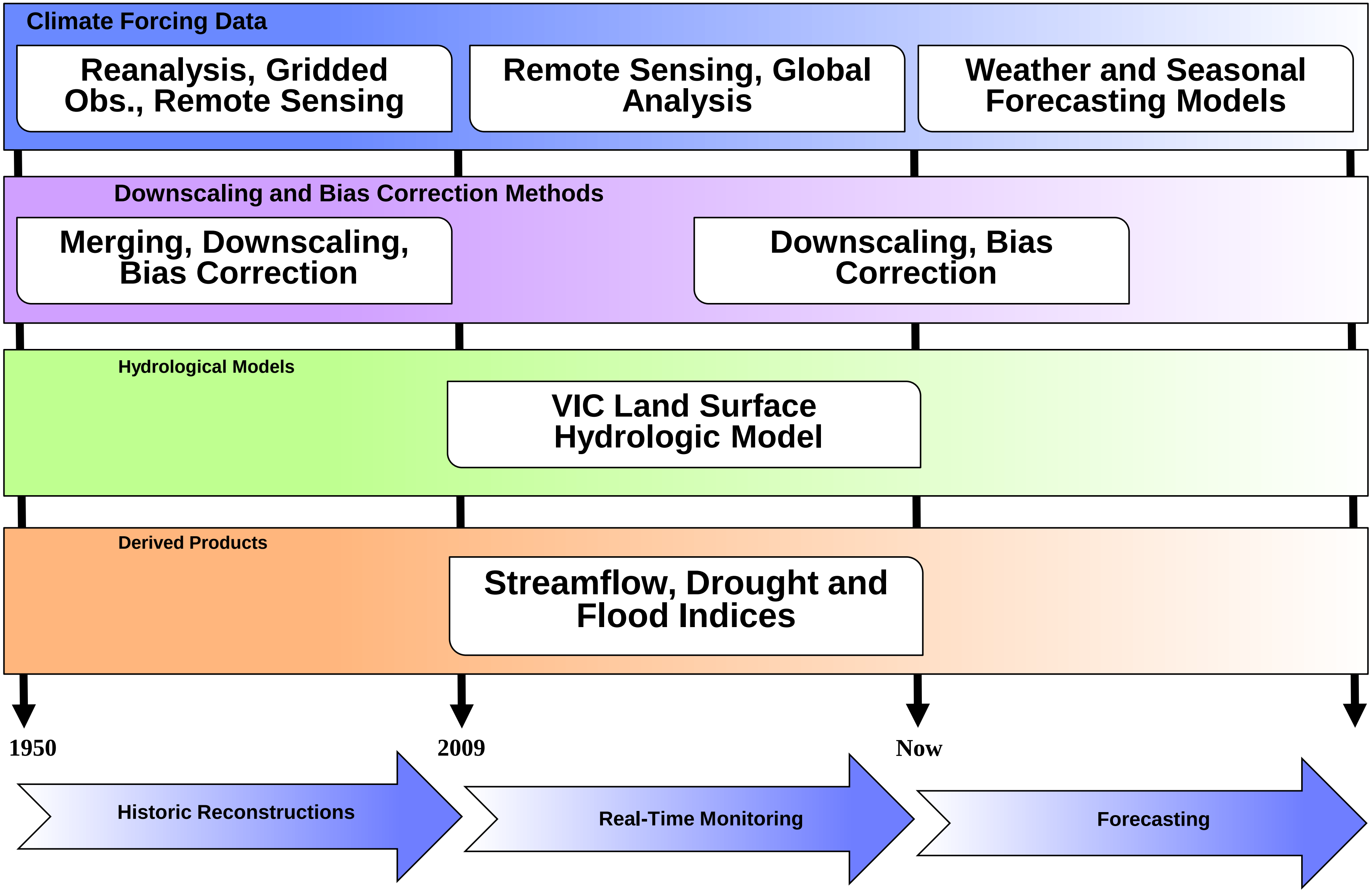
How is the weather model data processed in order to use in the land surface model?

1. Initial conditions provide the temperature and wind speed data for 00,06,12,18 hours
2. The 3 hour forecast since the beginning of the run is also used (e.g. 00 -> 03 hour). - *There are 8 values of temperature and wind speed for a day.*
3. The minimum temperature, maximum temperature and mean wind speed are derived from GFS.
4. Use bilinear interpolation to downscale to ¼ degree spatial resolution.

Daily Maximum Temperature

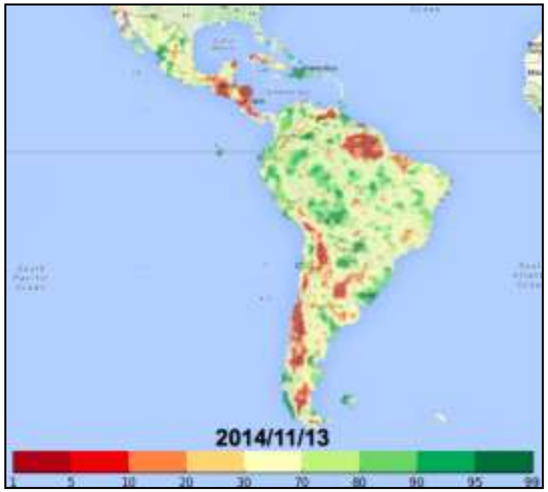


Part 3: Drought Products

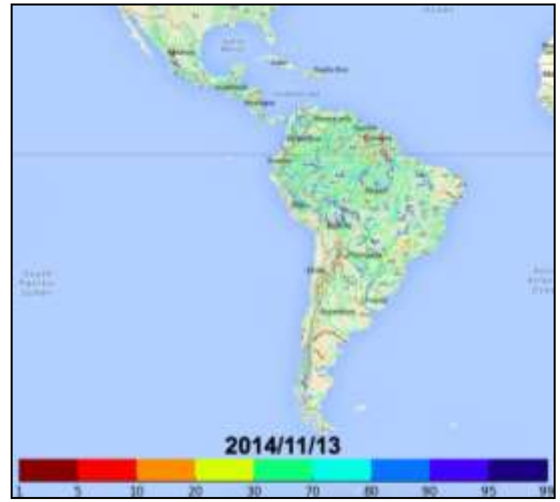


Part 3: Drought Products

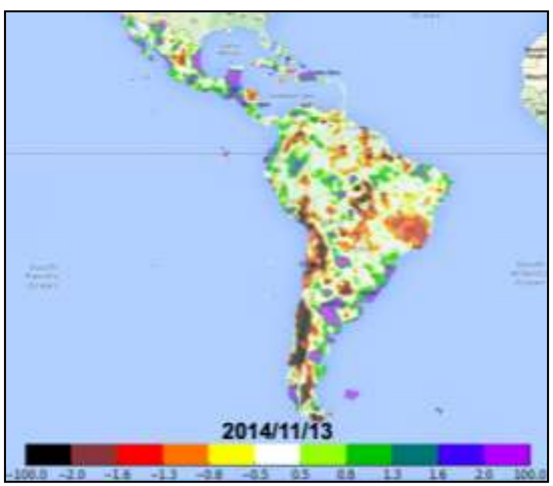
- Drought Index



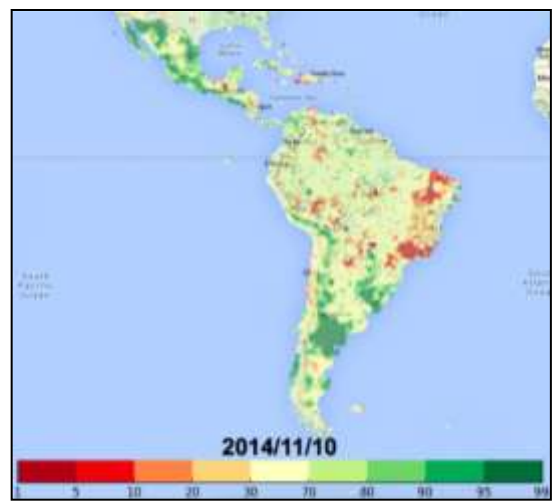
- Simulated Discharge Products



- SPI



- Vegetation (NDVI) Products



Drought Products: Drought Index

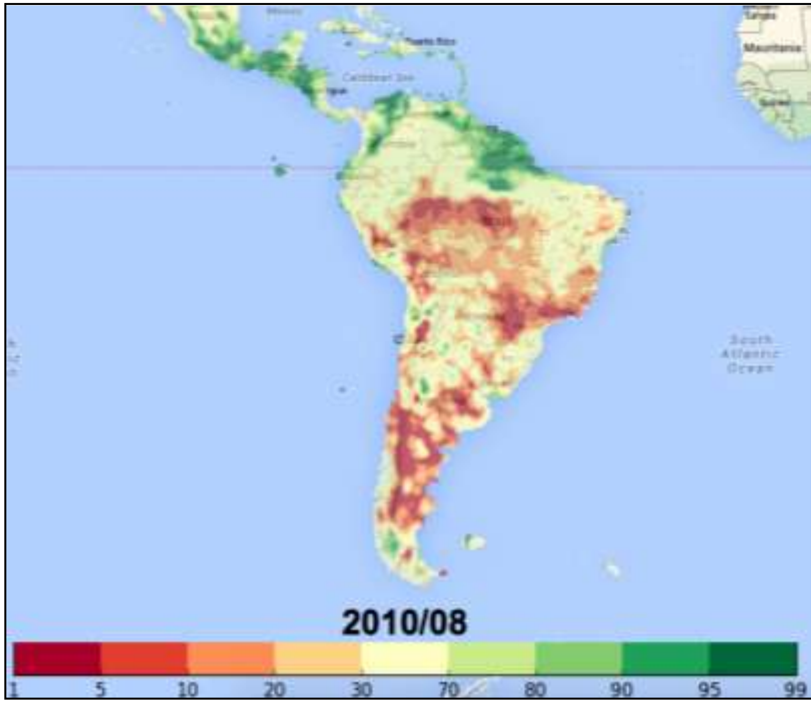
Drought Index - *Measure of the severity of drought; low values indicate drought conditions.*

Steps to calculate:

1. Calculate the relative soil moisture of the sum of the land surface model output of layers 1 and 2

2. Find the percentile of the day in question by comparing it to the climatology provided by the historical simulations (1950 - 2008).

- ***The index is the resulting percentile***.

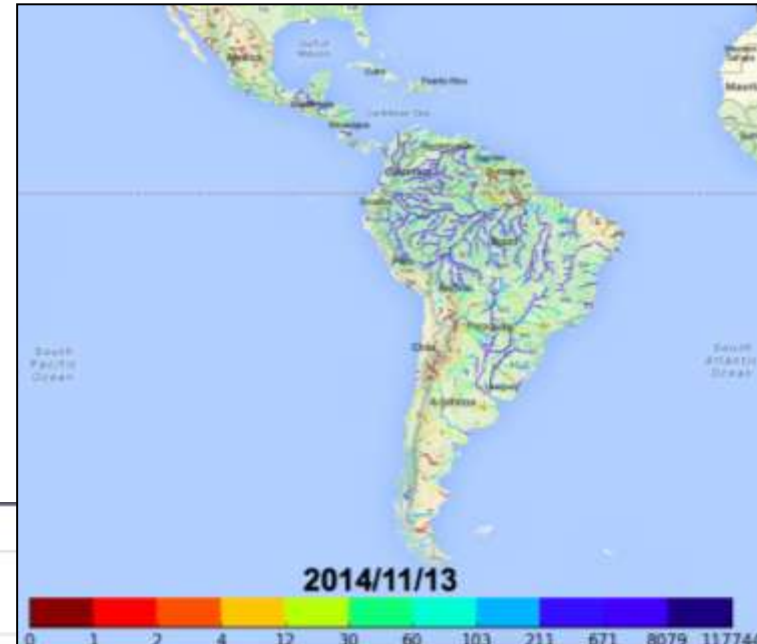


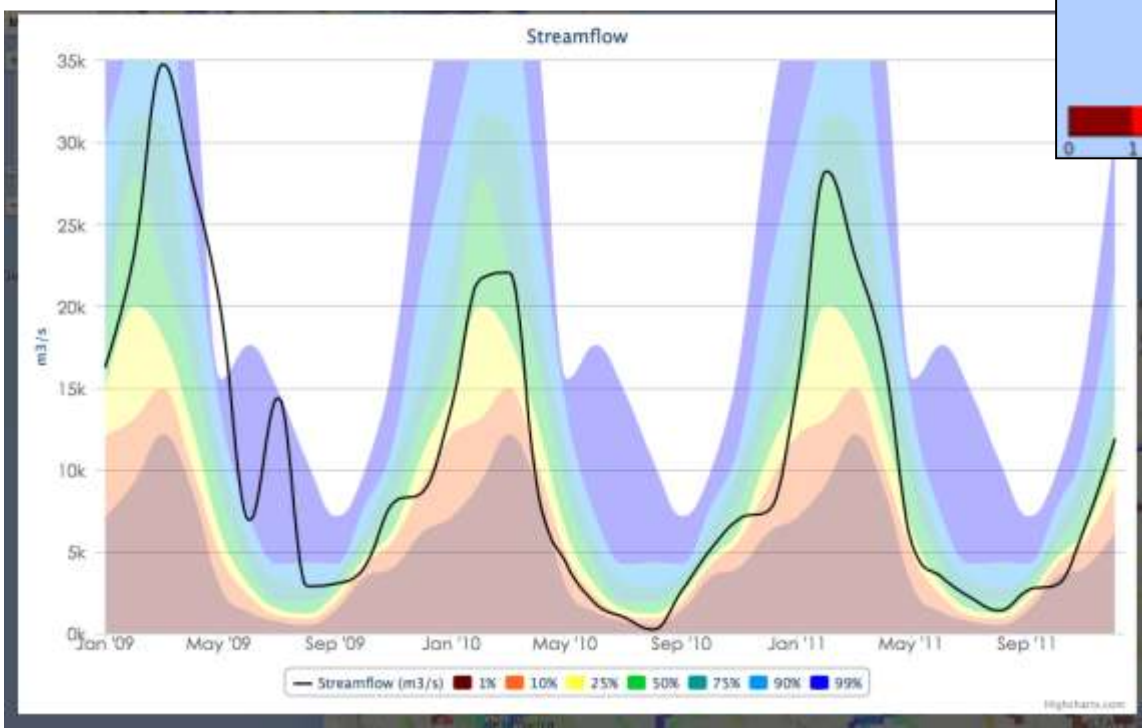
- **What historical information do we use?**
  - The VIC land surface model is run between 1950 and 2008.
  - We assume that this time period establishes the climatology to which compare drought conditions.

Drought Products: Streamflow Percentiles

Streamflow Percentiles- *<u>Measure of the severity of hydrologic drought; low values indicate drought conditions.</u>*

- Gridded estimates of discharge that can easily be viewed as time series
- Percentiles derived from historical VIC model runs

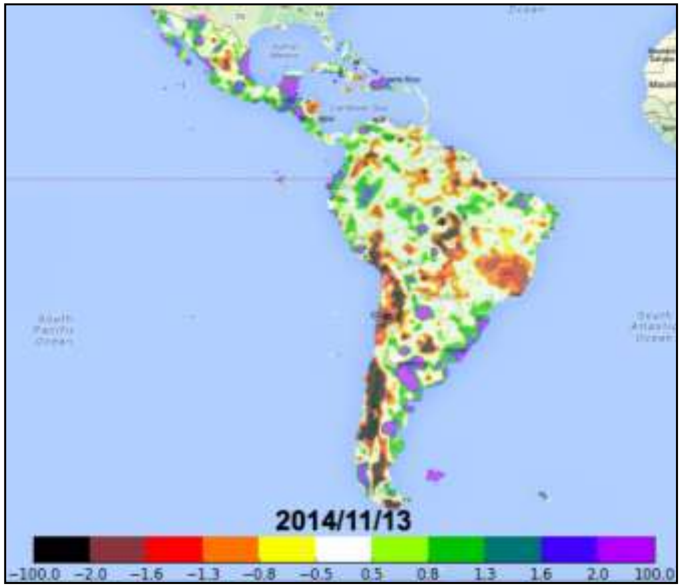


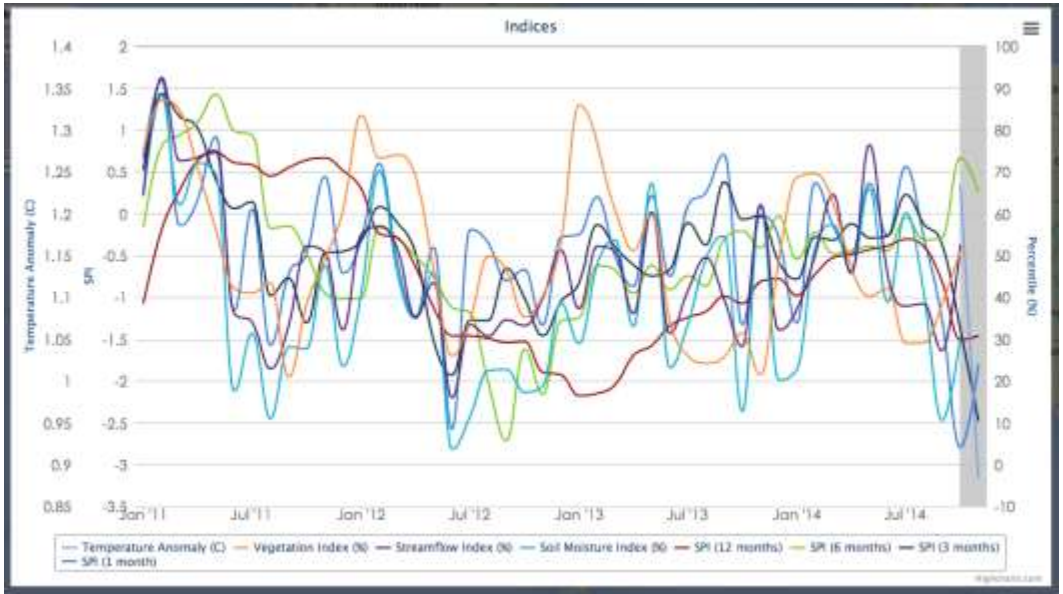


Drought Products: SPI

SPI – *<u>The standardized precipitation index is the number of standard deviations that observed cumulative precipitation deviated from the climatological average. Low values indicate meteorological drought.</u>*

- This product is calculated for 1, 3, 6 and 12 month cumulative precipitation.

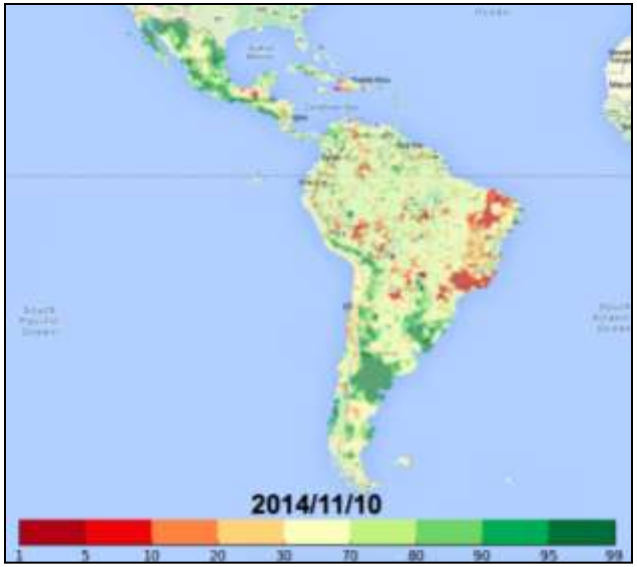


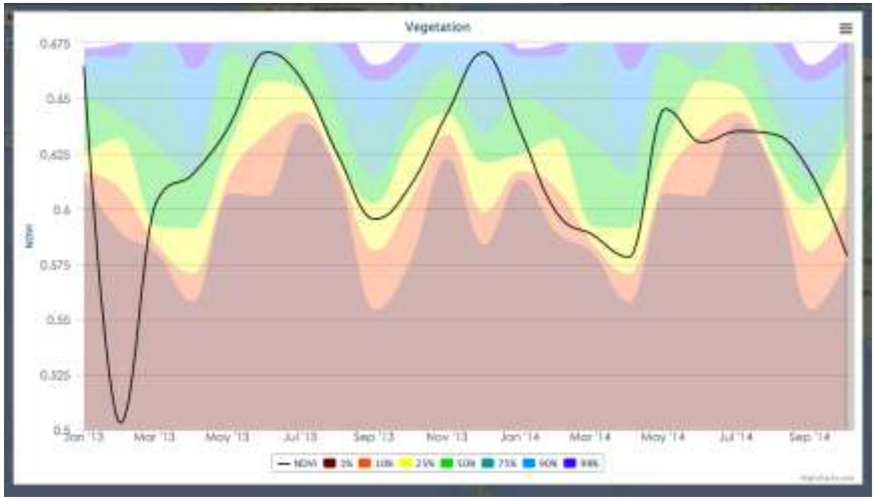


Drought Products: Vegetation Indices

NDVI – ***Normalized Difference Vegetation Index is a measure of live green vegetation; Changes to low values typically correlate well with drought conditions.***

NDVI Percentiles –
A measure of the severity of agricultural drought. Low values indicate drought conditions. The 30-day moving average of NDVI is compared to the historical record of NDVI via the empirical cumulative distribution derive a percentile.





Drought Monitoring Technical Summary