Climate and Human Impacts on Water Resources in Africa

Michael T. Coe[1] Navin Ramankutty[1], Charon Birkett[2], and Kaiyuan Li[1]

[1] Center for Sustainability and the Global Environment, University of Wisconsin-Madison

[2] Earth System Science Interdisciplinary Center, University of Maryland at College Park

Goal -- Use satellite and ground-based data and numerical models to better understand drivers of water resource variability in semi-arid Africa

Specific objectives:

1. Quantify land use/land cover history since 1950
2. Model impacts of climate and humans on water over last 50 years
3. Investigate applications of satellite tools and numerical models for assessment of near-term water resources

1. Quantify land cover/use history

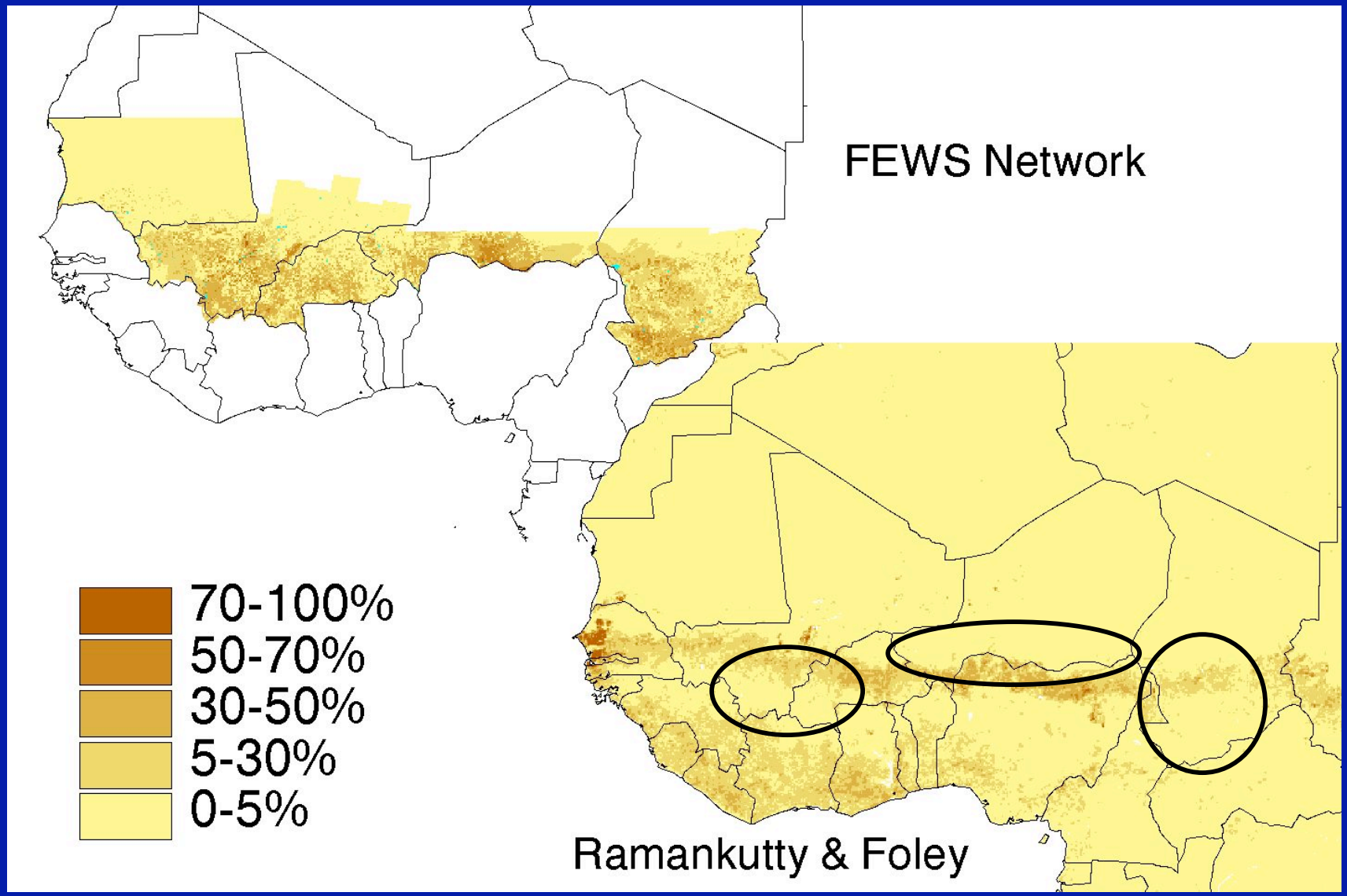
Problem: need to create spatially explicit data of land cover for semi-arid Africa

- *Clearing for agriculture has been important in last 50 yrs*
- *Cropland parcels tend to be small and dispersed*
- *Moderate-resolution satellite data seems to be inadequate*
  - *Wall-to-wall Landsat classification expensive*
- *Crop census data is not spatially explicit*
- *No one data source is adequate*

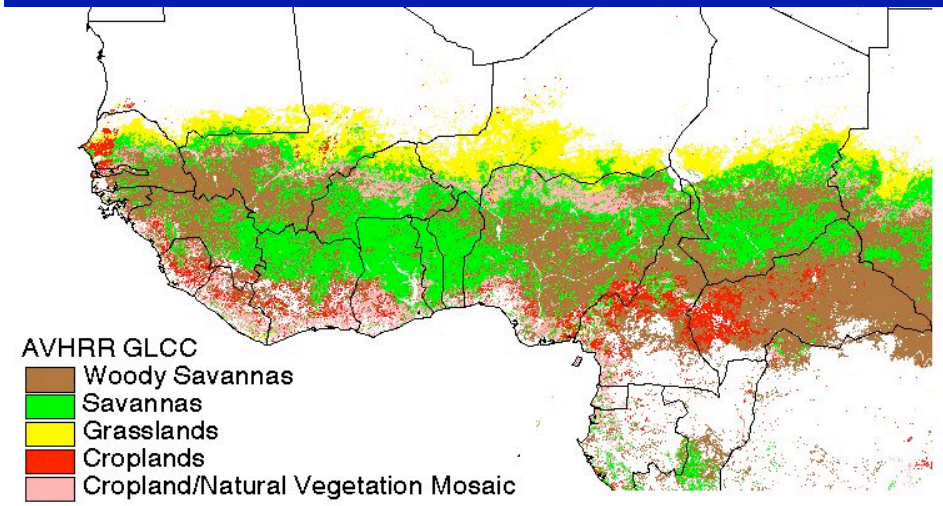
Solution: merge available data to get improved product

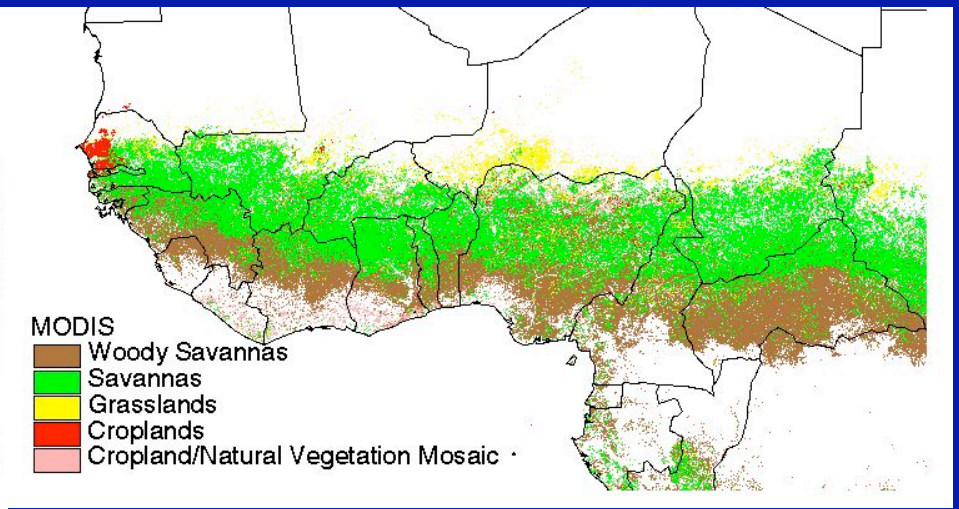
- *Combine satellite, agricultural and population census data*

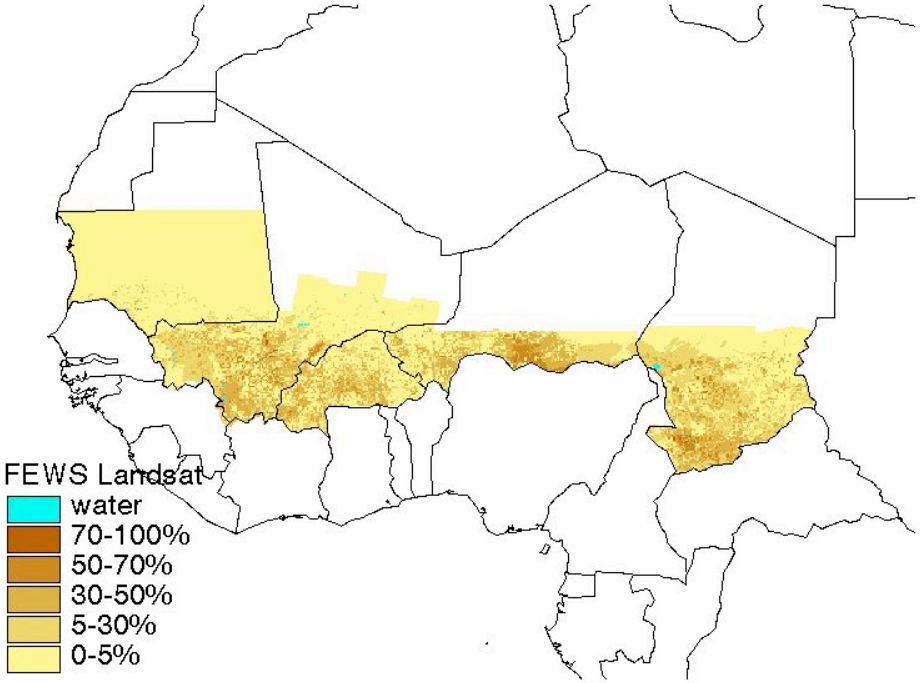
Initial merged product --How good is the Ramankutty & Foley (1998) croplands data in the Sahel?



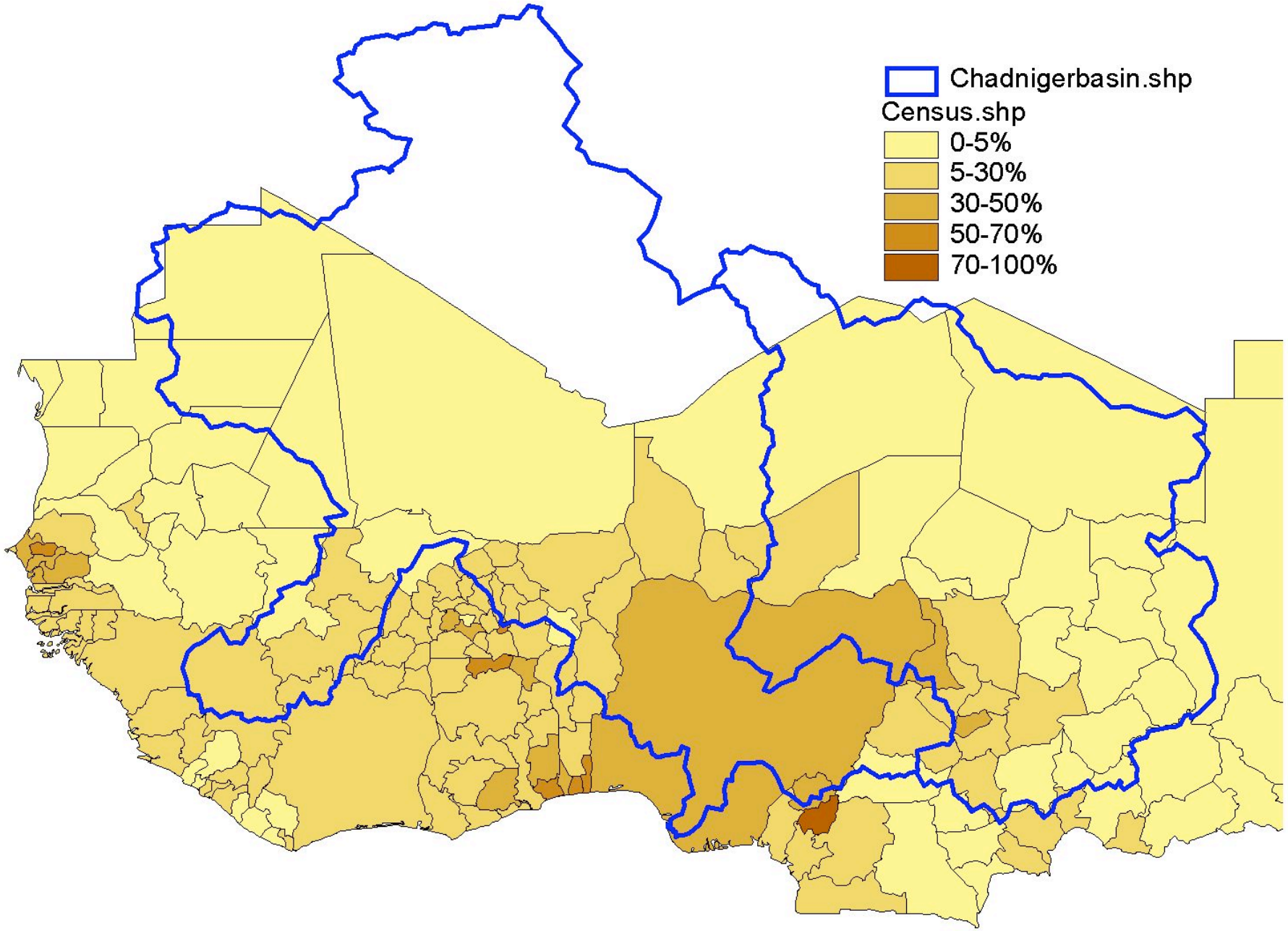
How good are the Moderate Resolution Satellite (AVHRR, MODIS) based land cover data products?



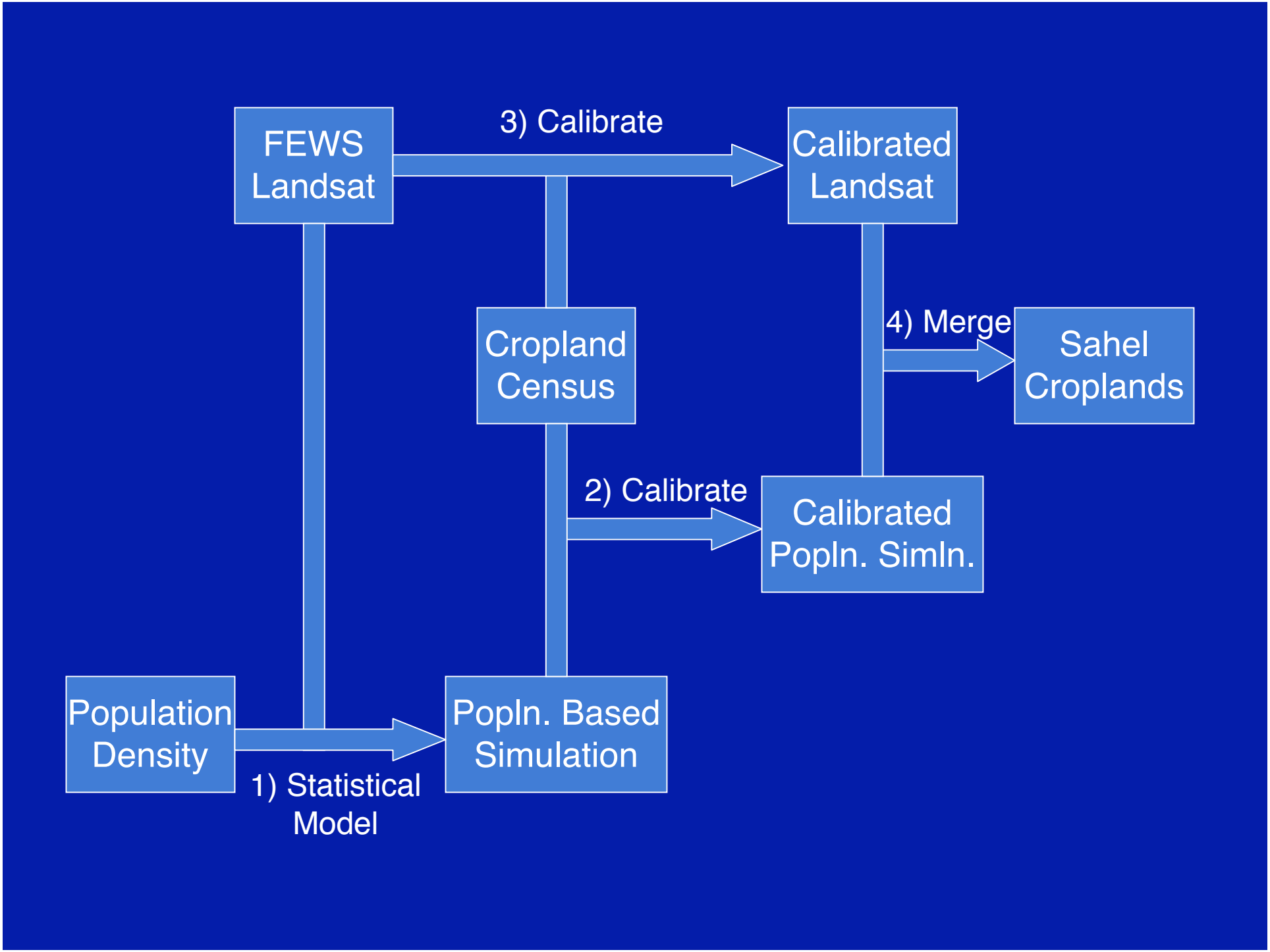


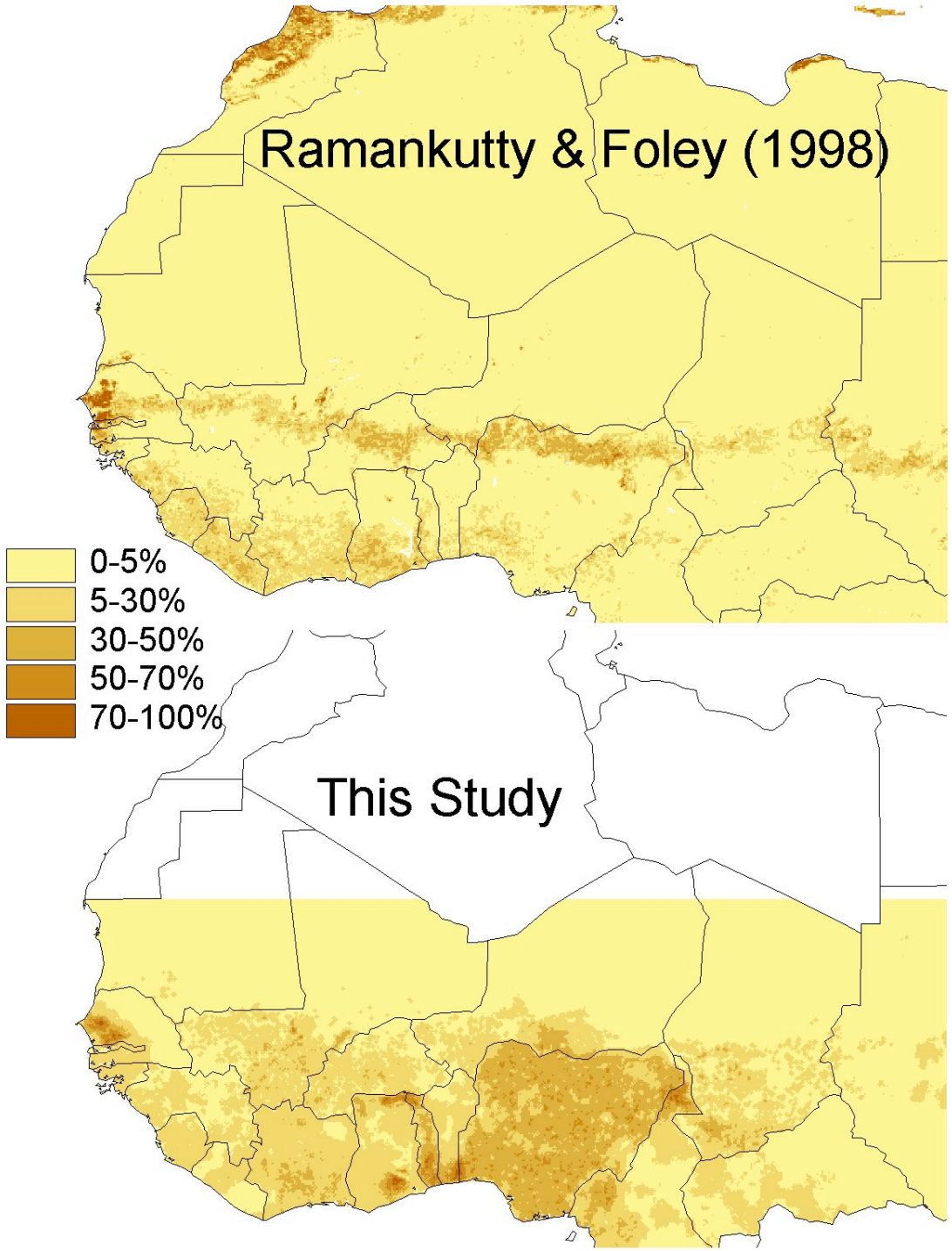


Census data on croplands from subnational crop harvested area statistics



Until we can improve satellite-based algorithms, is there a way to quickly derive a product, for use in models by integrating the various sources of data?

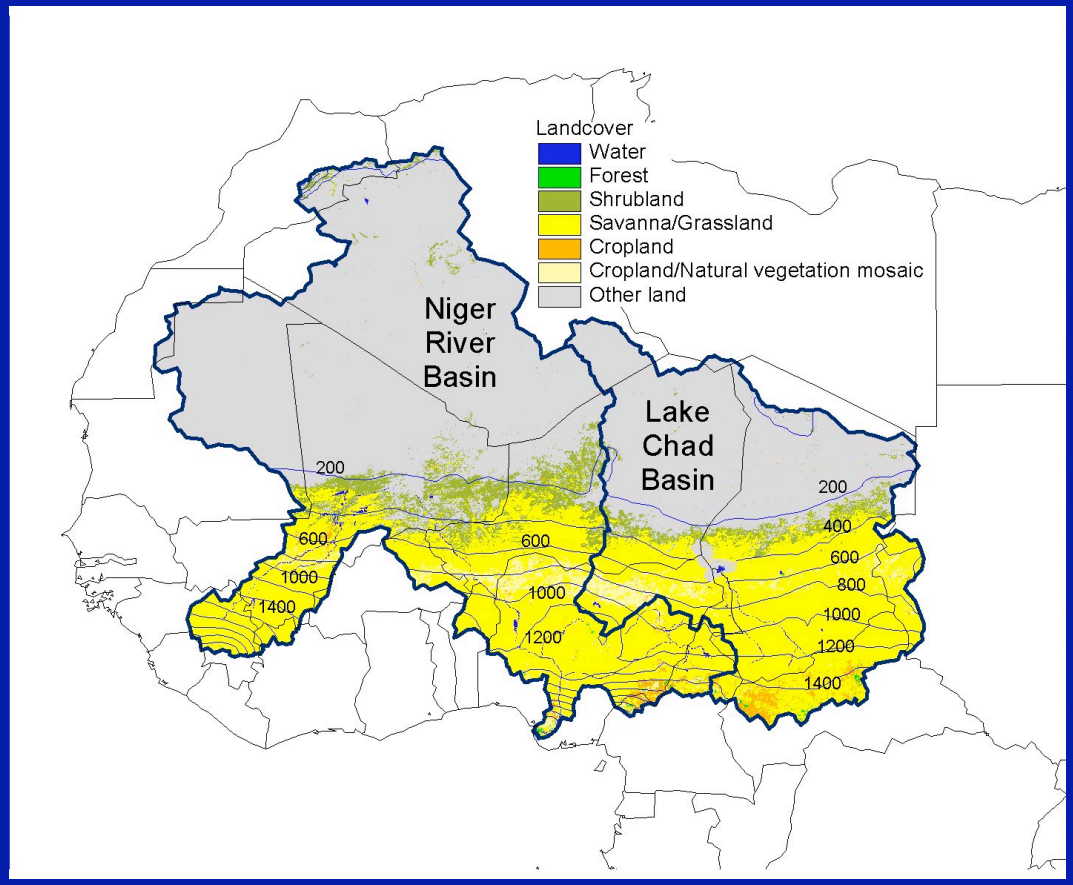

FEWS Landsat
3) Calibrate
Calibrated Landsat
Cropland Census
4) Merge
Sahel Croplands
2) Calibrate
Calibrated Popln. Simln.
Population Density
1) Statistical Model
Popln. Based Simulation


Ramankutty & Foley (1998)
0-5%
5-30%
30-50%
50-70%
70-100%
This Study

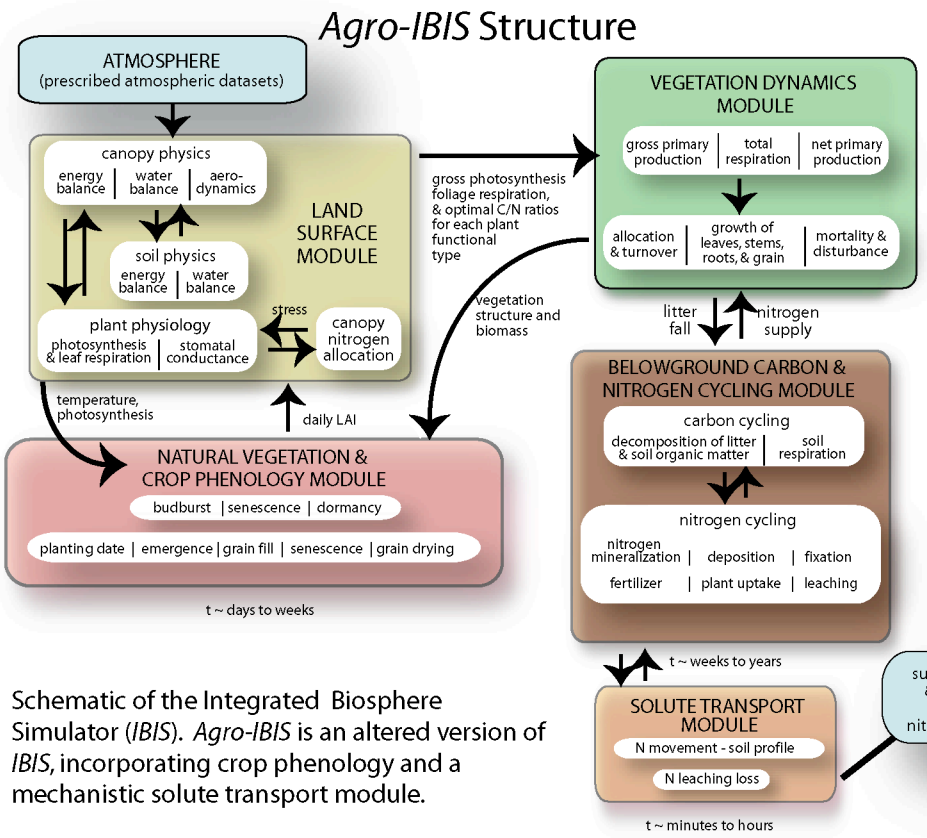
2. Model variability of runoff, discharge, and surface waters

Use physically based, spatially explicit models to simulate:

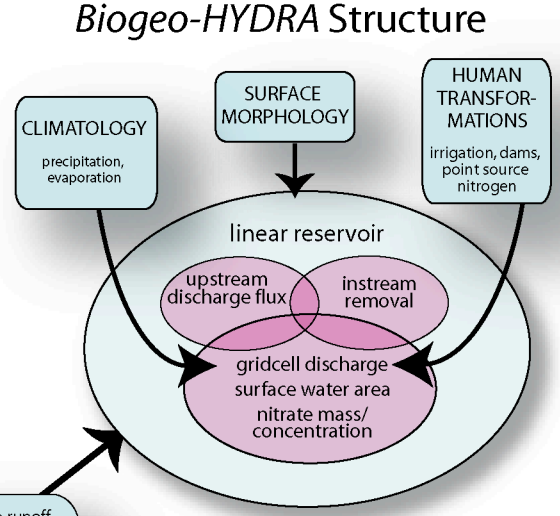
- runoff generation
- river flow
- wetlands and lakes



IBIS-HYDRA models



Schematic of the Integrated Biosphere Simulator (*IBIS*). *Agro-IBIS* is an altered version of *IBIS*, incorporating crop phenology and a mechanistic solute transport module.



Schematic representation of the input and products of the *HYDRA*

- *Partitions incoming precipitation and radiation into evaptranspiration and runoff*
- *Routes runoff across landscape to simulate rivers, lakes, and wetlands*

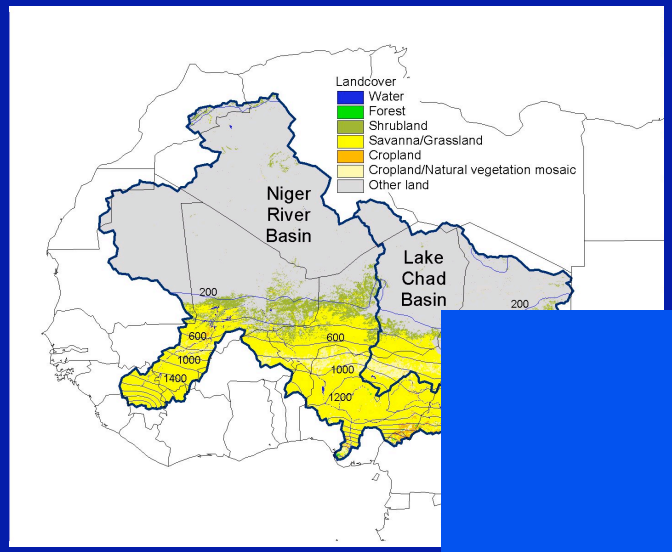
Problem: simulating runoff and discharge in semi-arid regions difficult

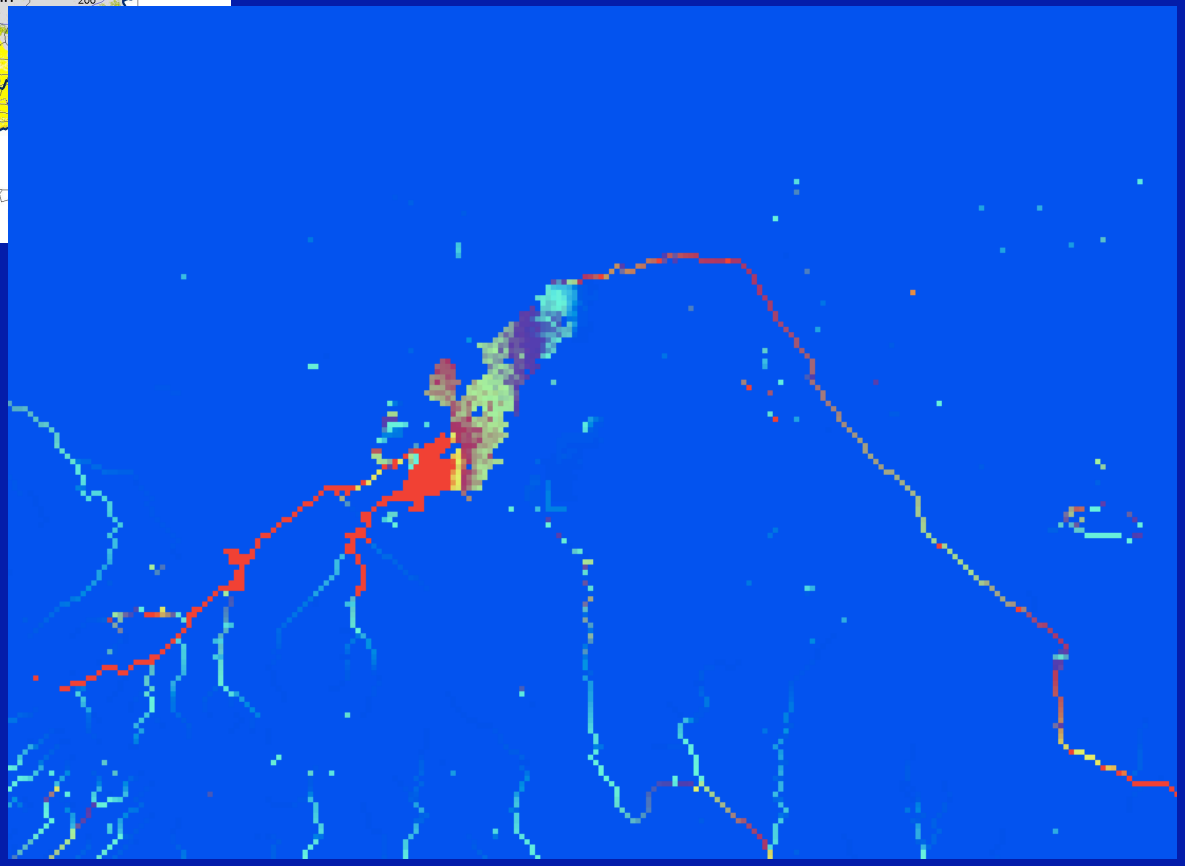
- *Runoff is less than 5% of precipitation*
- *Dynamics of soil infiltration and root water stress become very important*
- *Evaporation from wetlands and rivers large part of budget*

Solution: improve IBIS and HYDRA models

- *Include Green-Ampt function to improve soil water infiltration*
- *Represent deep root profile - 5% of roots > 2m depth*
- *Allow for variable root water uptake (compensation for dry soil layers)*
- *Use cellular automata to simulate flow across land surface*

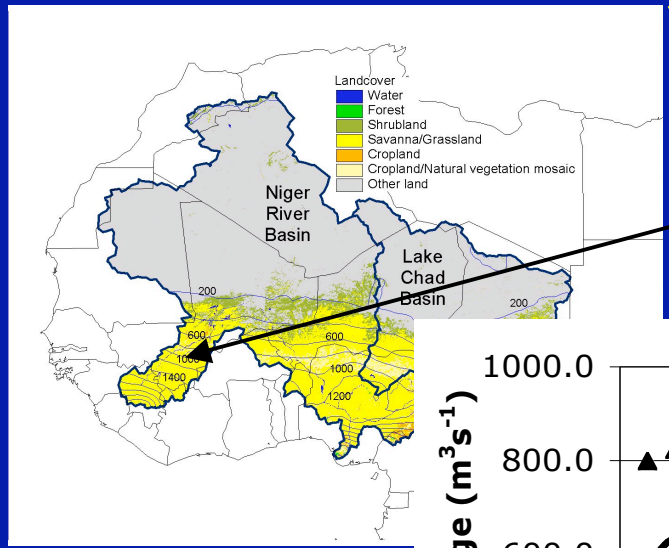
Niger basin



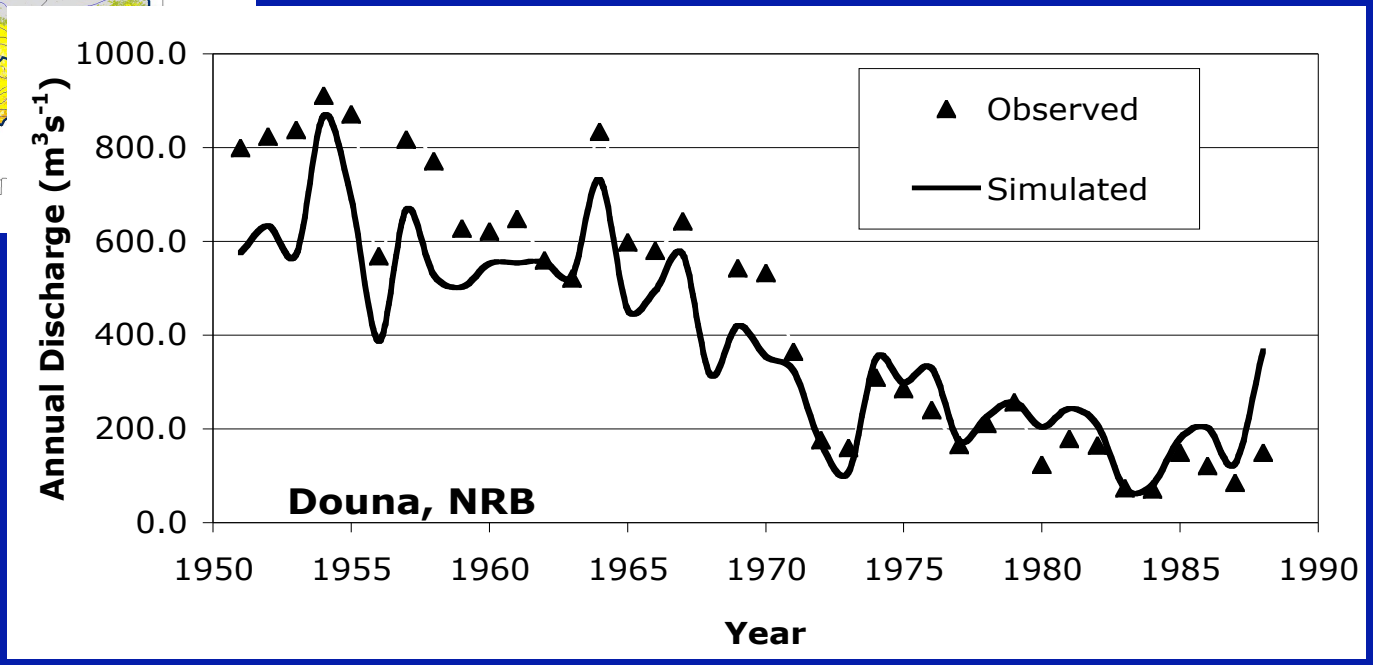


- *Simultaneously calculate river flow and wetland extent and depth*
- *Impacts water balance through evaporation from water surface*

Discharge

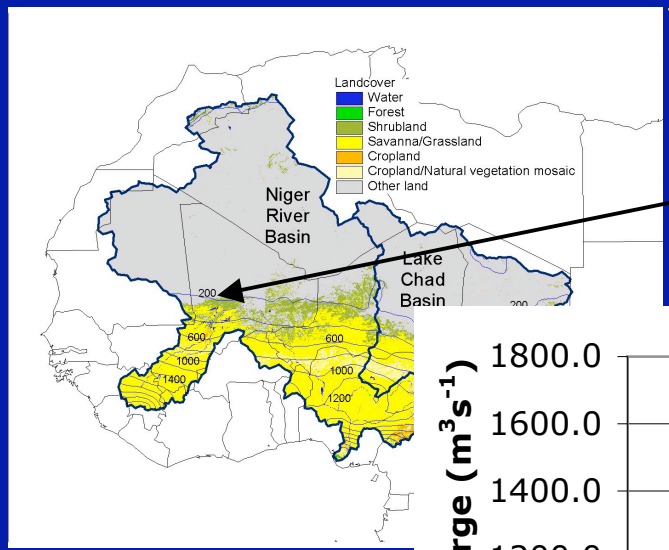


Niger Basin at Douna

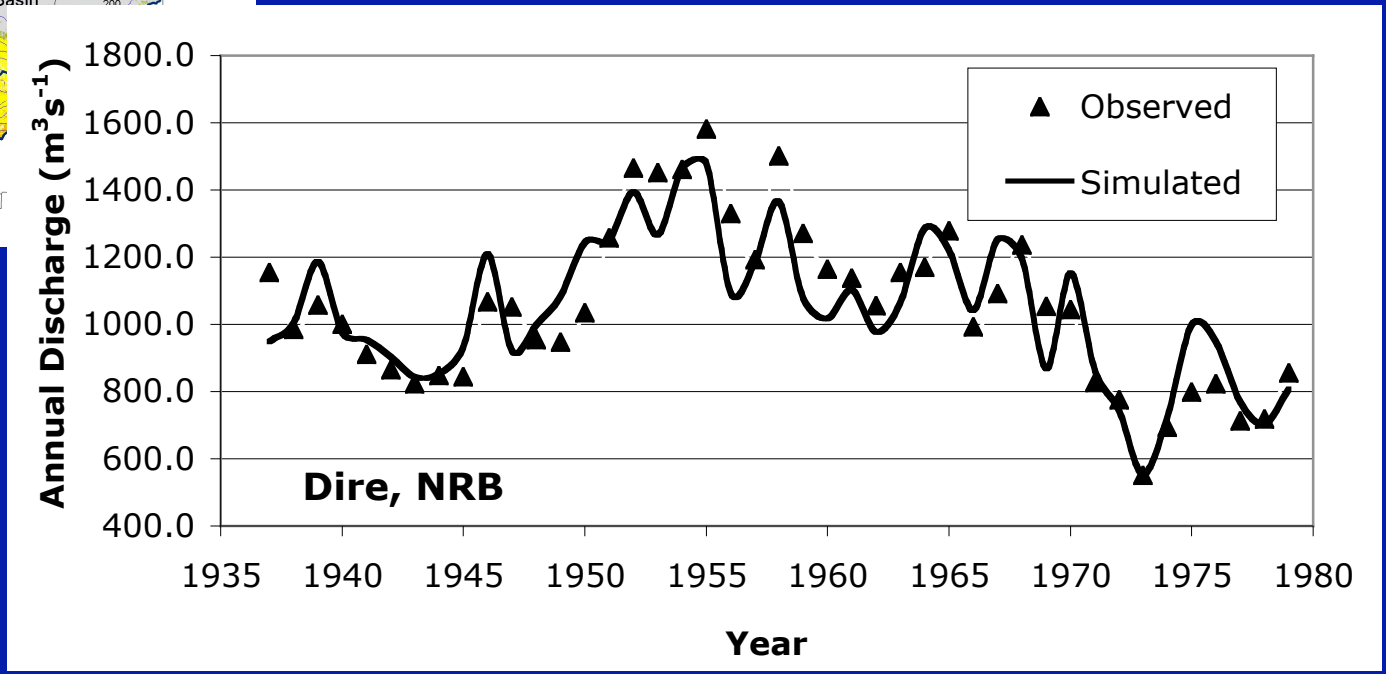


- Inter-annual variability
- Persistent long-term wet and dry period

Discharge

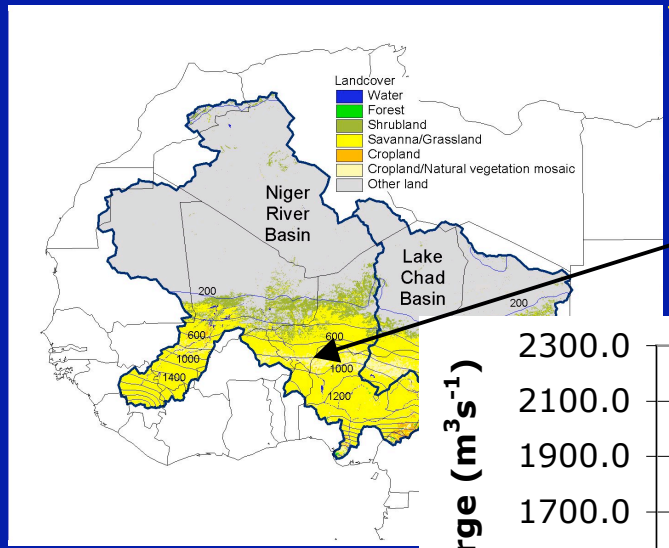


Niger Basin at Dire

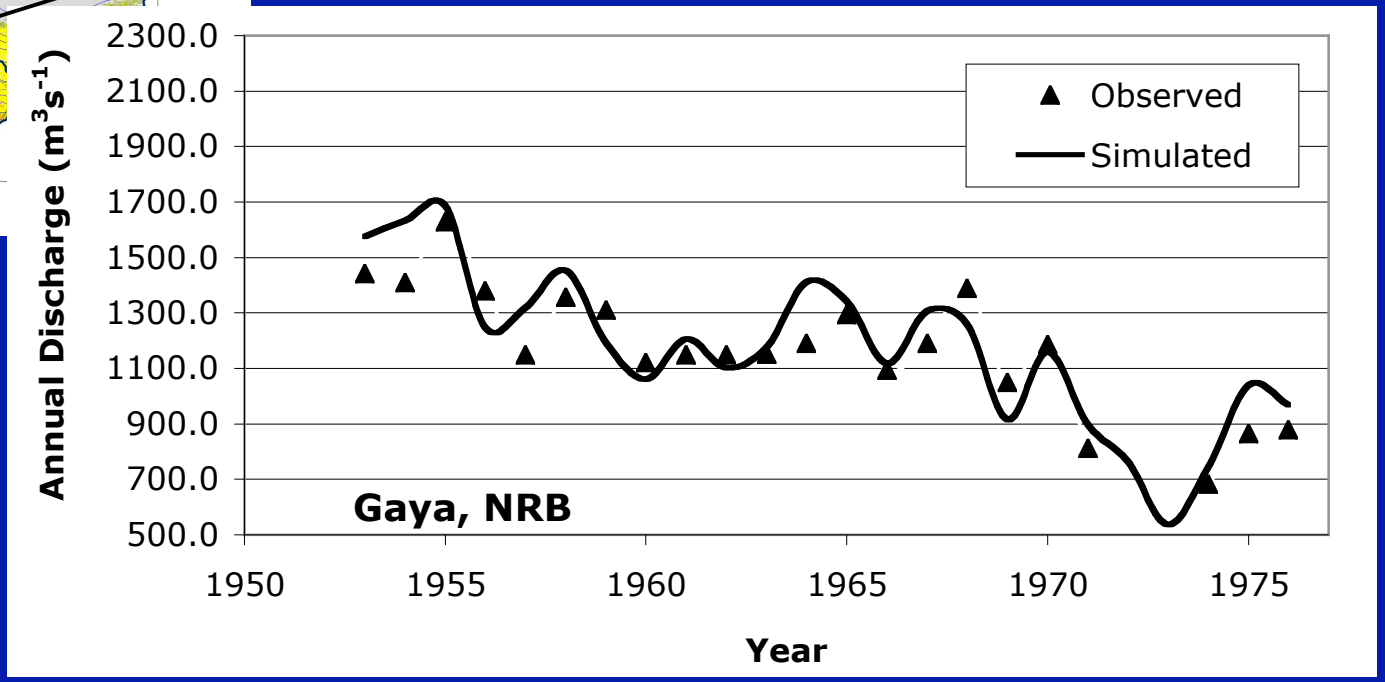


- Inter-annual variability
- Persistent long-term wet and dry period

Discharge



Niger Basin at Gaya

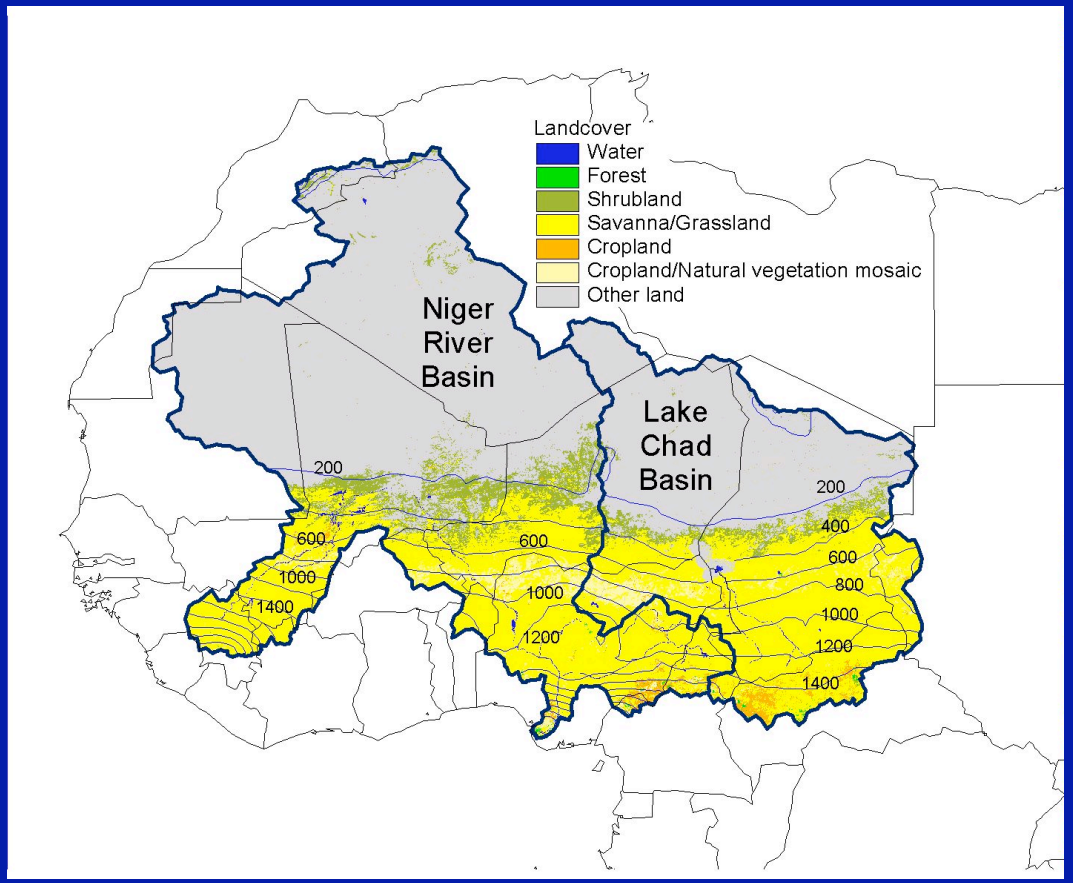


- Inter-annual variability
- Persistent long-term wet and dry period

3. Evaluate tools for near-term prediction

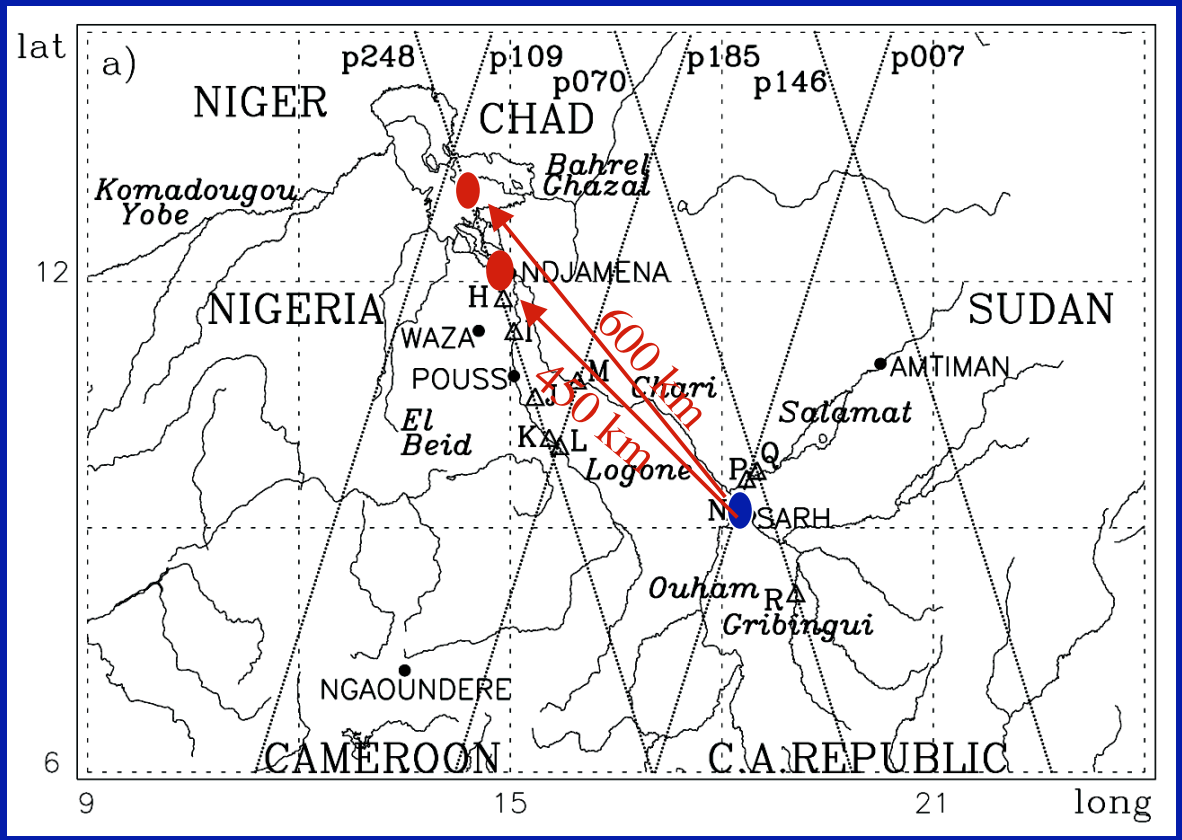
Problem: predict seasonal water resources in Lake Chad Basin

- *Population dependent on seasonal fluctuation of Lake Chad water level*
- *Inter-annual variability can be large and impacts livelihoods*
- *Advance knowledge may be of use locally*



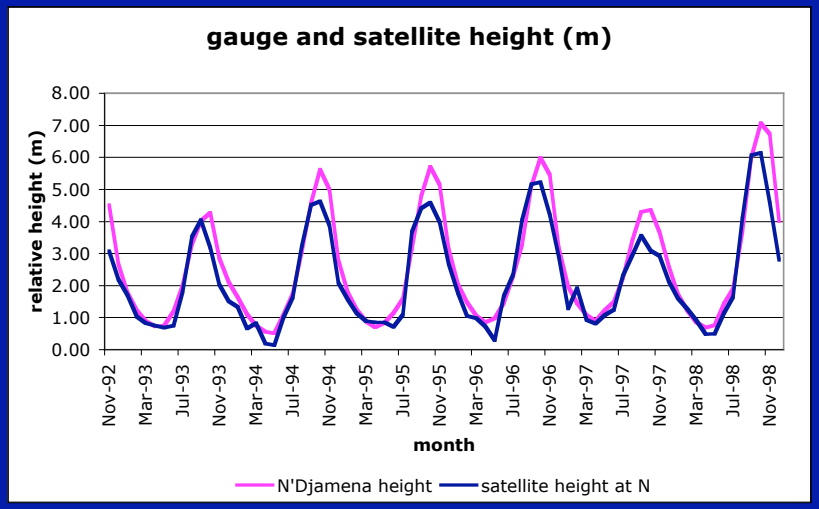
Solution: use satellite radar altimetry from upstream location and calibrate with downstream data to provide downstream discharge and height

- *Calculate downstream discharge and height from upstream water height*
- *Predictive due to travel-time of water from upstream to downstream*
- *Fast - get results potentially within days*



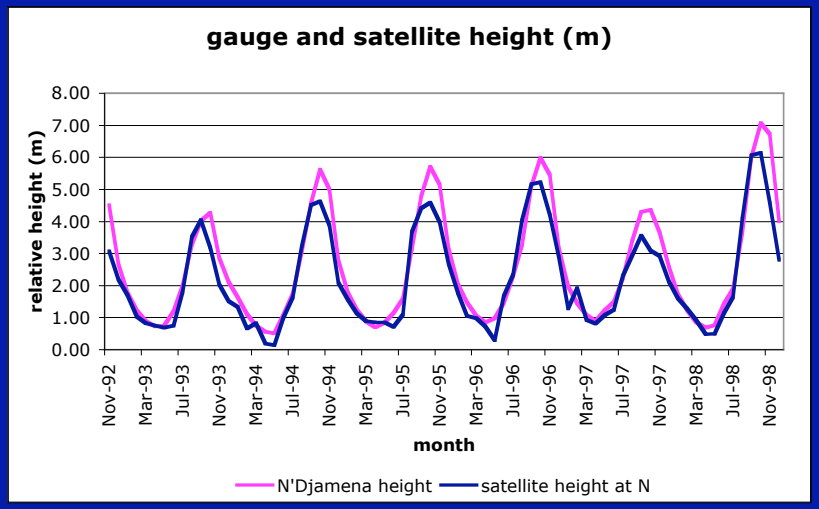
Derive discharge from altimetry at N'Djamena

Find phase lag

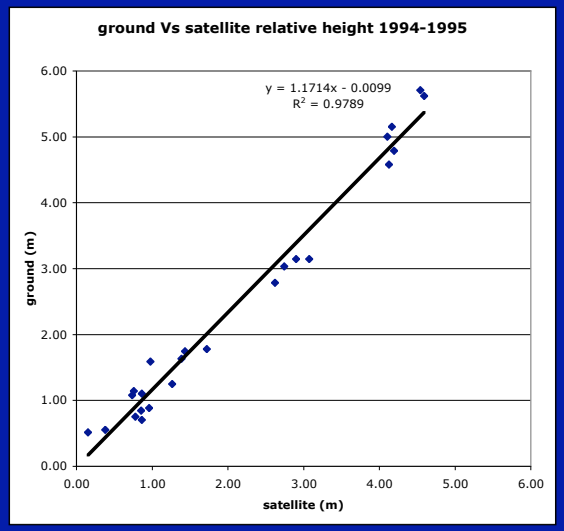


Derive discharge from altimetry at N'Djamena

Find phase lag

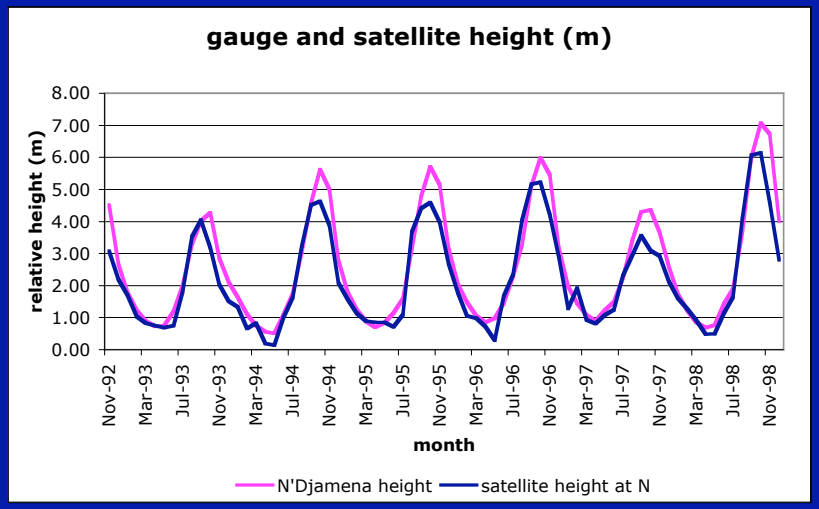


Lag correlation

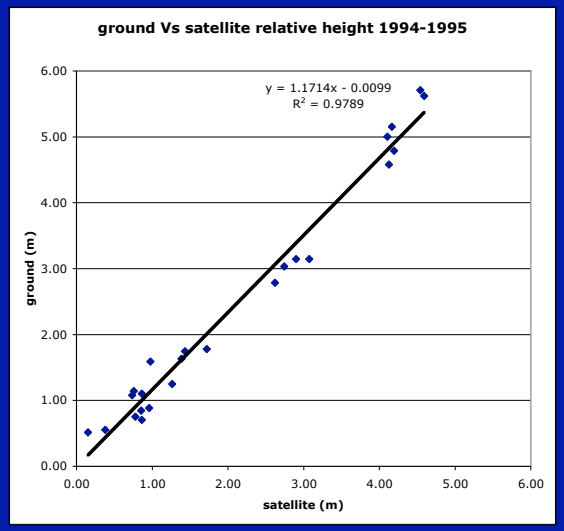


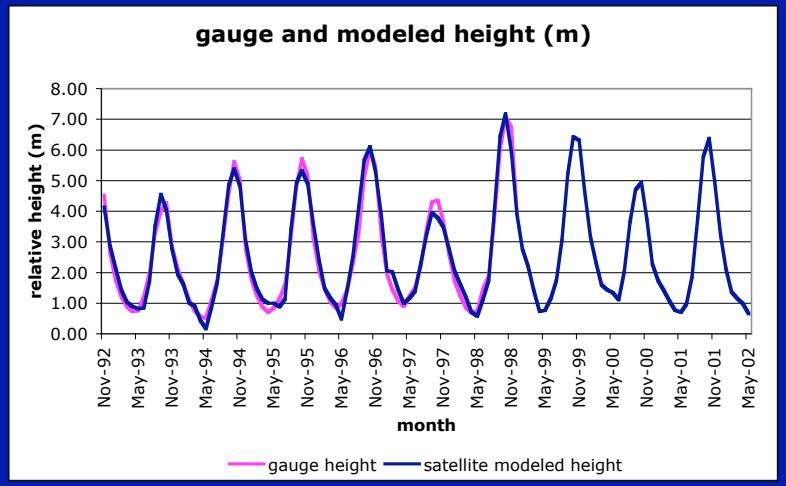
Derive discharge from altimetry at N'Djamena

Find phase lag



Lag correlation



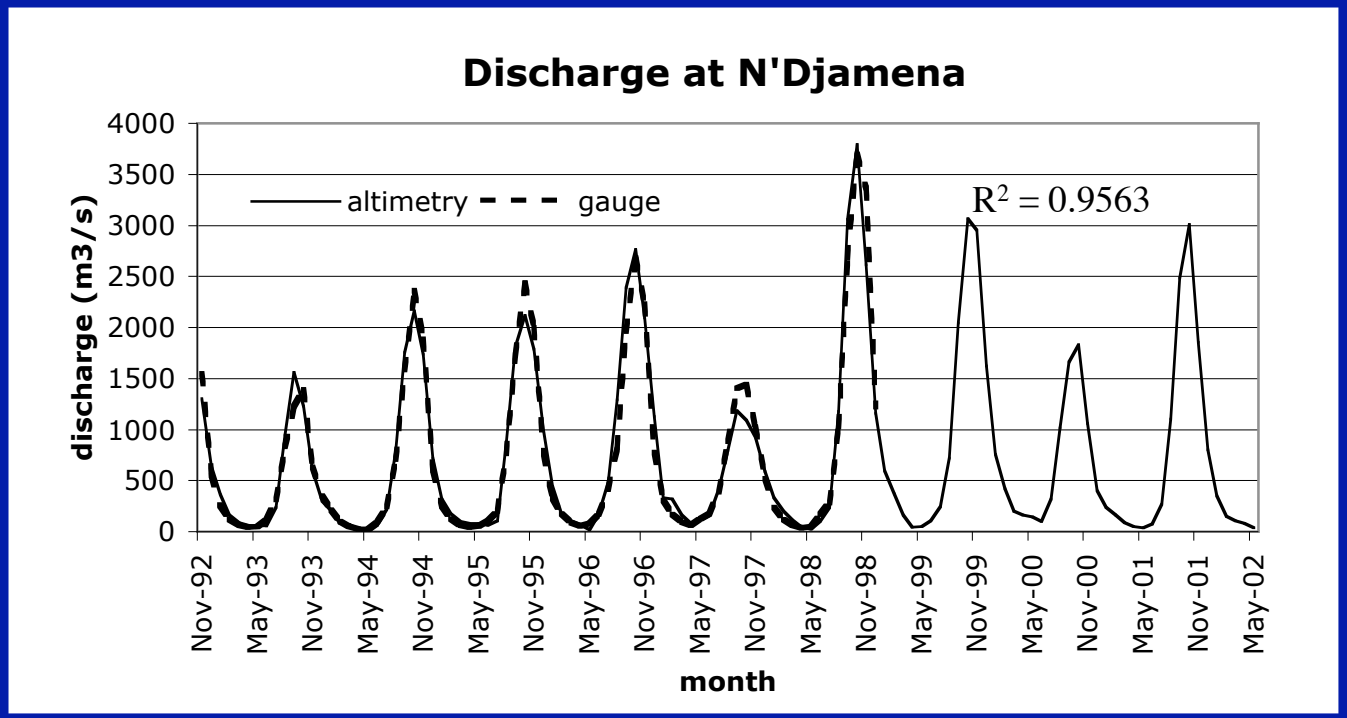


Best fit

Convert to ground ($r^2 = .9682$)

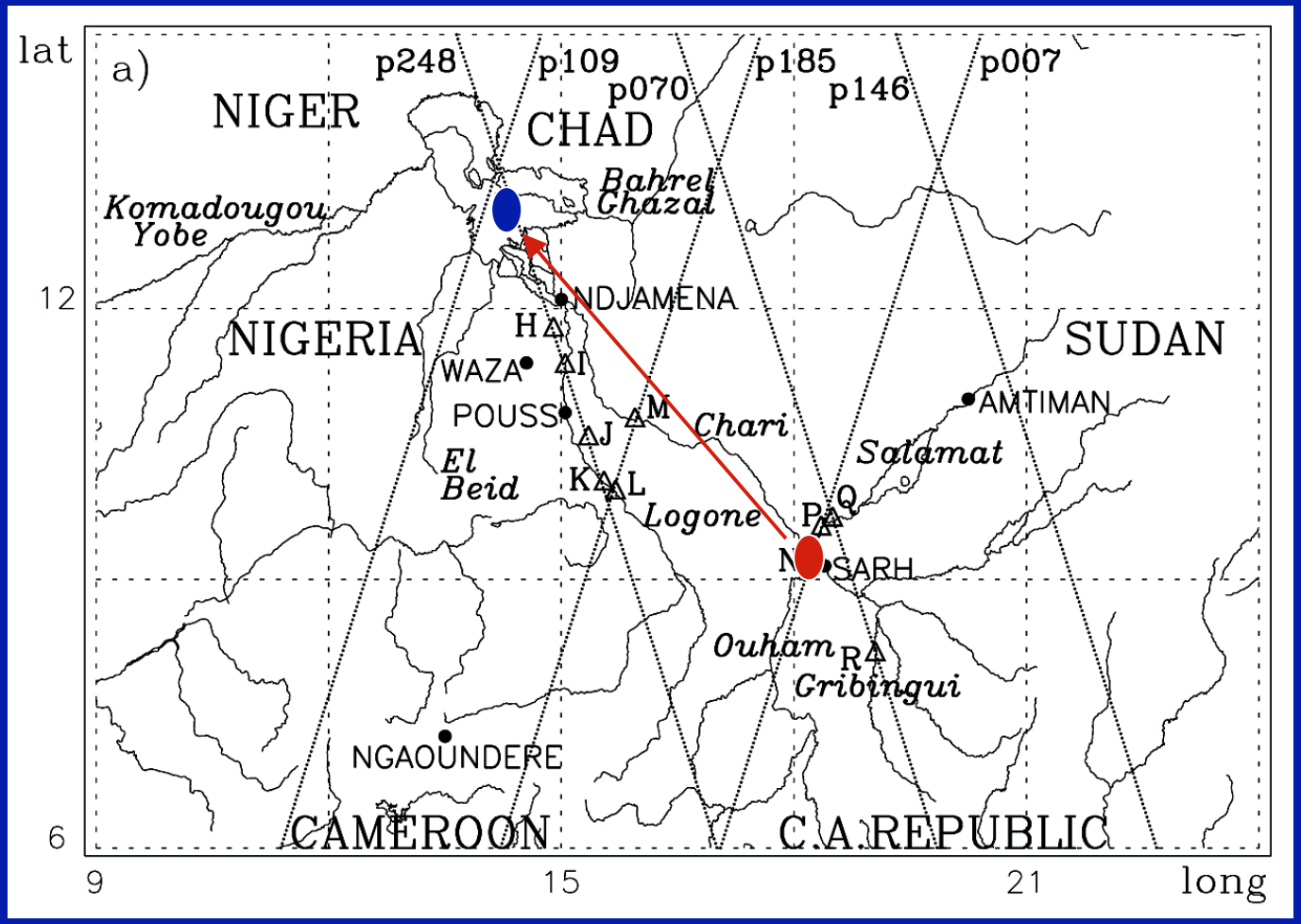
Derive discharge from altimetry

-apply ground-based rating curve



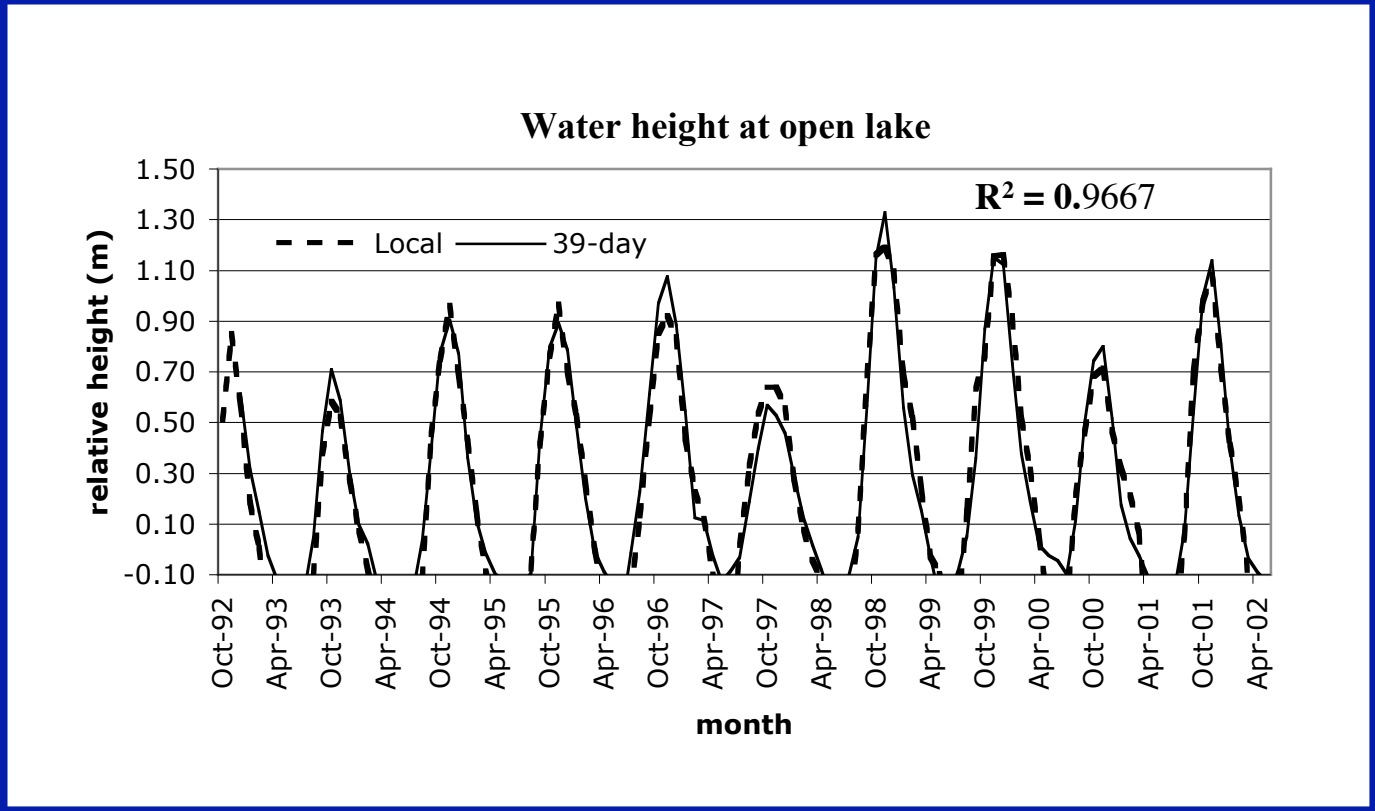
- Extends surface record to September 2002
- 10 days in advance (450 km apart)

Lake Height



- Site N to Sites on lake
- > 600 km distance
- Near-term prediction

Lake Height



- Height on lake from 600 km upstream ($r^2 = 0.9667$)
- 39 days in advance of lake level change

Future

- Develop land cover/use history (since 1950) on same procedures
- Perform simulations to better understand role of land use/cover changes in last 50 years in water resource variability
- Merge satellite predictive tools with models to get more explicit predictions of river discharge, wetlands, lake height and area
- Set up near-real time product of discharge and height

Thank You