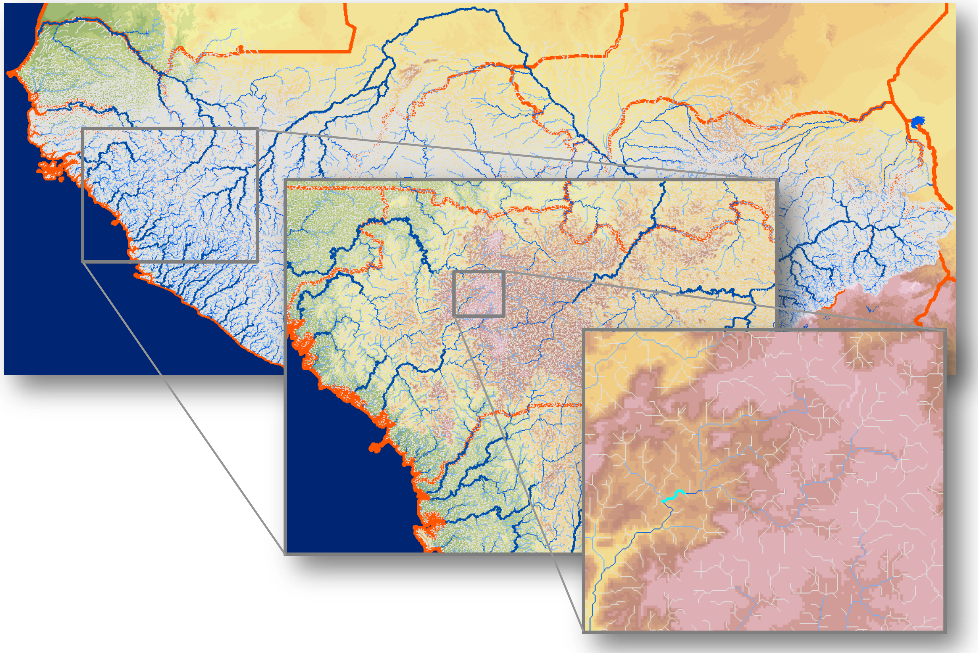
GIS Hydropower Resources Mapping for ECOWAS Region

Session 2:

Data challenges & Lessons learned



Training, Dakar, Senegal, July 2016

Trainer: Harald Kling

Pöyry, Hydro Consulting, Hydropower, Austria

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PÖYRY ECREEE Towards Sustainable Energy

Data challenges & Lessons learned

Overview

- **Geo-referencing in GIS**

  Gauges, Dams

- **Data availability in different periods**

  Observed discharge, rainfall data sets

- **Data processing**

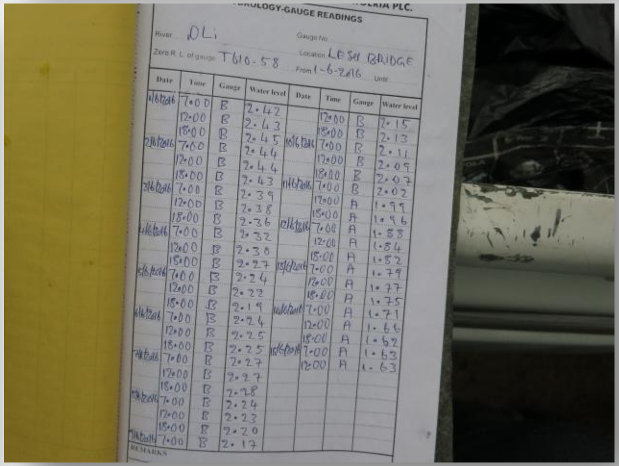
  Software issue

- **Lessons learned**

- **Group discussion**

Discharge measurement

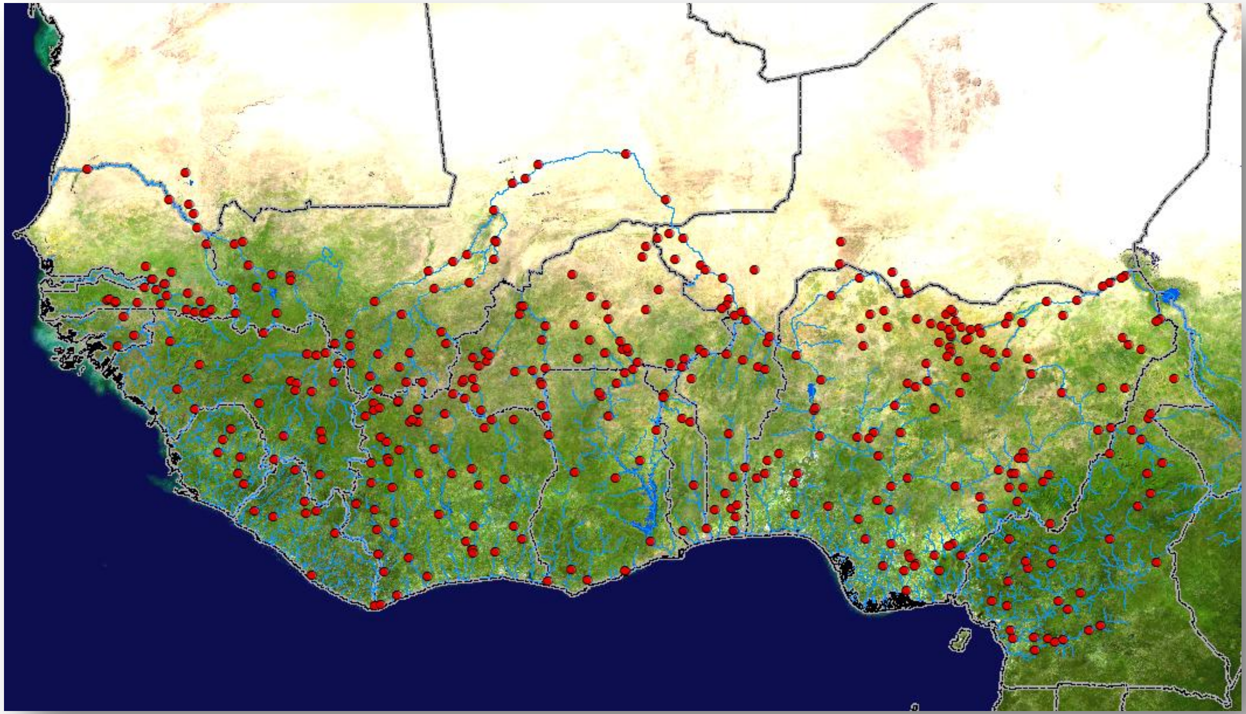
Some gauges in Nigeria



- Work of gauge readers is extremely important!
- Water level measured once or thrice a day
- Often manual readings with hand-written records
- Rating curve required to convert water level (m) to discharge (m^3/s)

Discharge measurement in West Africa

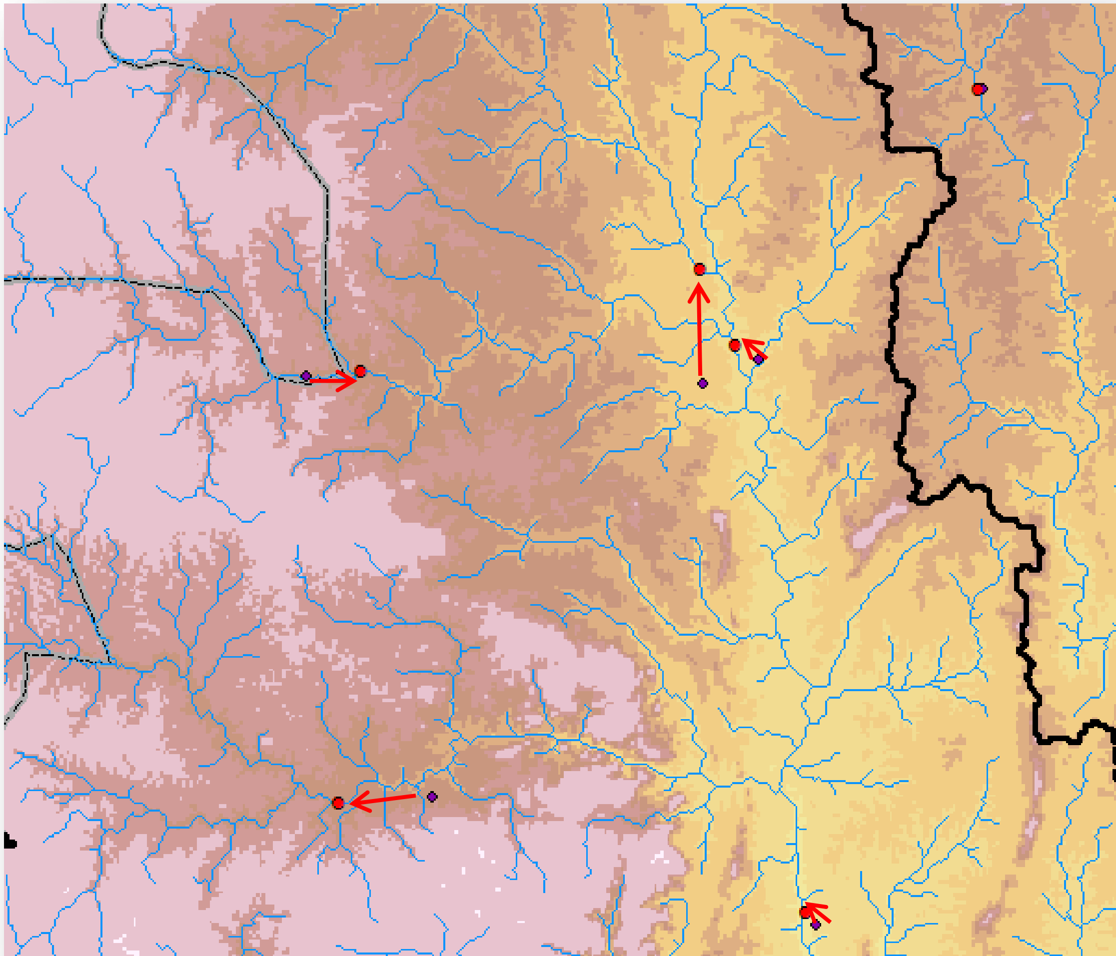
410 discharge gauges available for this study



- 360 gauges obtained from GRDC
- 50 gauges obtained from
  - River Basin Organizations
  - National Hydrological Services
  - JICA
- Hardly any gauges located at small rivers that are suitable for small-scale hydropower.
- Gauge data cover different observation periods.
- Inaccurate geo-referencing major problem before data can be used for modelling study

GRDC discharge gauges

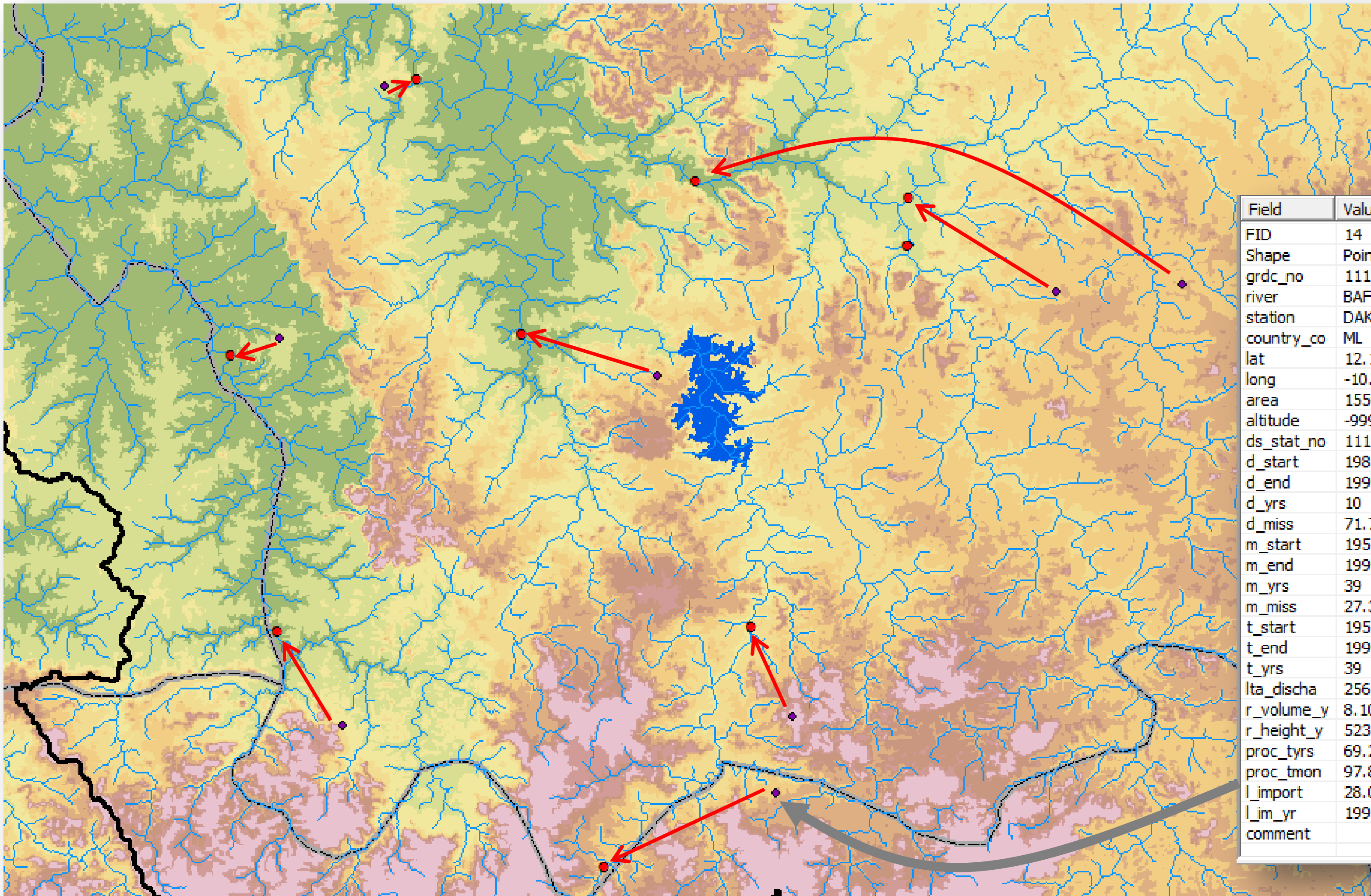
Manual geo-referencing required in GIS



- Requirement for further GIS work
  - Gauges must be located at river network
- Information used
  - River name
  - Gauge name (Where is this village?)
  - Satellite image (Where is nearest bridge or river access?)
  - Area reported vs. area computed.
  - Country
  - Sierem data base (inaccurate!)
  - Reports (Google search)
- Typical errors
  - Insufficient decimal places for latitude & longitude, e.g. lat = 7.5°
  - Inaccurate coordinates
  - Typing error
    e.g. lat = 7.531 -> lat = 8.531

GRDC discharge gauges

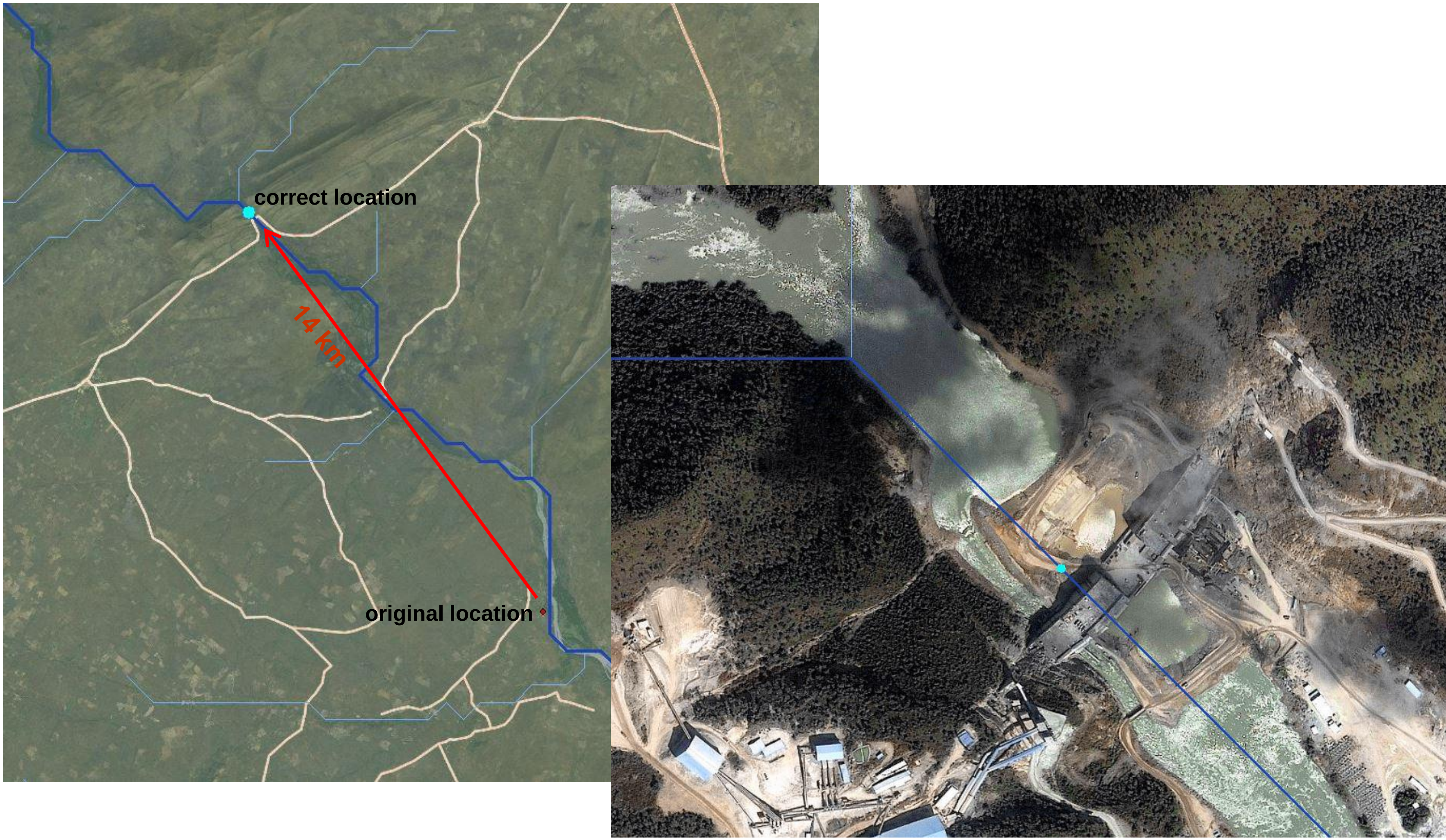
Manual geo-referencing required in GIS



Field	Value
FID	14
Shape	Point
grdc_no	1112480
river	BAFING (TRIB. ATUI, SENEGAL)
station	DAKA SAYDOU
country_co	ML
lat	12.15
long	-10.2
area	15500
altitude	-999
ds_stat_no	1112500
d_start	1981
d_end	1990
d_yrs	10
d_miss	71.71
m_start	1952
m_end	1990
m_yrs	39
m_miss	27.37
t_start	1952
t_end	1990
t_yrs	39
lta_discha	256.922
r_volume_y	8.102
r_height_y	523
proc_tyrs	69.2
proc_tmon	97.8
l_import	28.02.1992
l_im_yr	1992
comment	

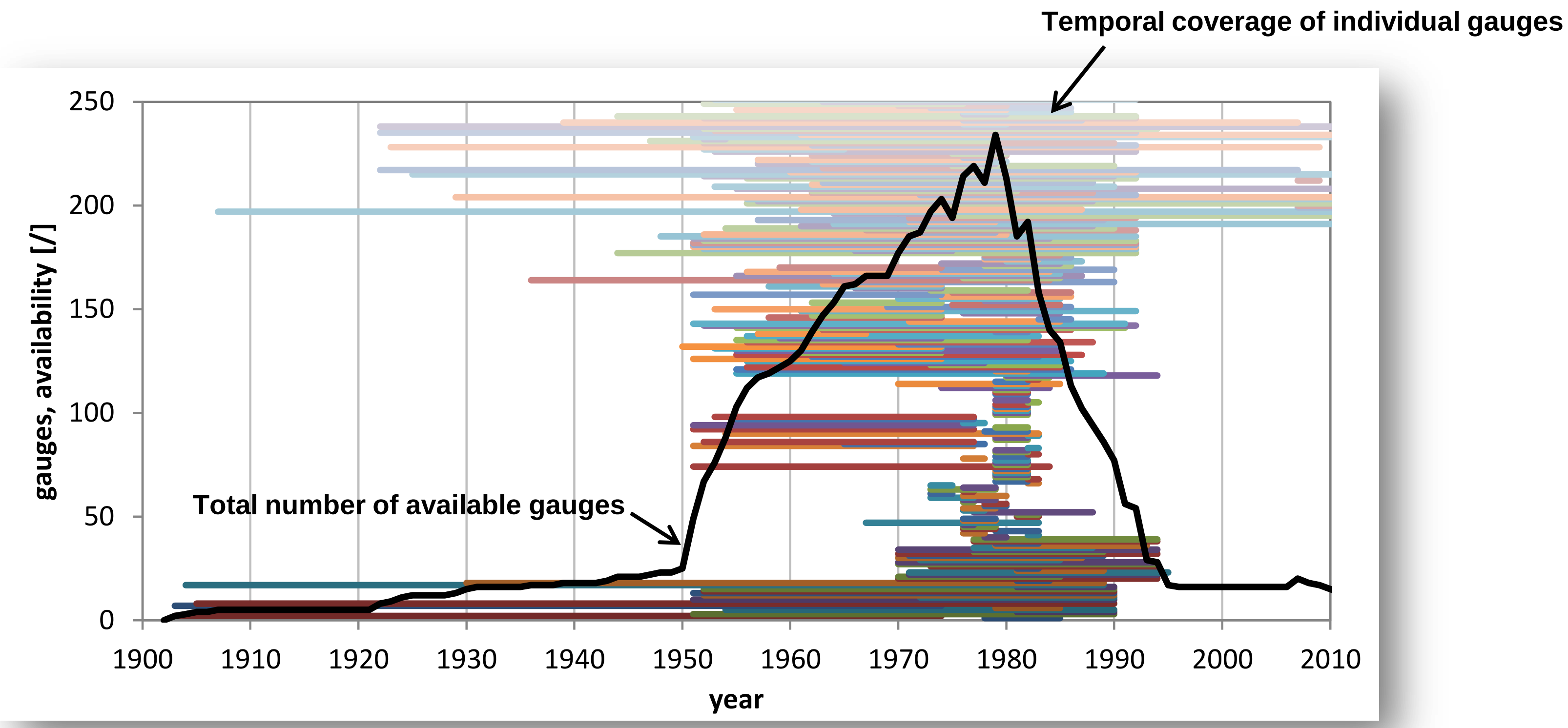
Existing hydropower plants layer

Geo-referencing example: Bui HPP in Ghana (recently constructed)



Temporal data availability

GRDC discharge data (daily)



Notes:
Only 250 out of 361 gauges displayed.
Missing data not visualized (data gaps!)

Data quality

Questionable discharge data at some gauges

Metchum @ GOURI 1051704503

Débit journalier 1051704505-1 (m3/s)

Latitude 6.2833

Longitude 10.0333

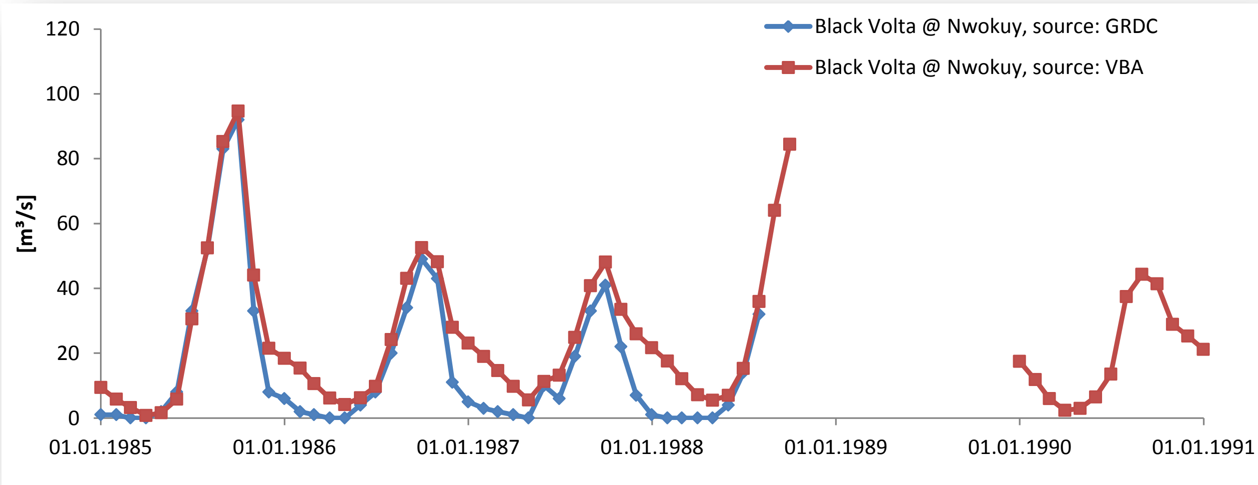
Aire du bassin versant 2116 km²

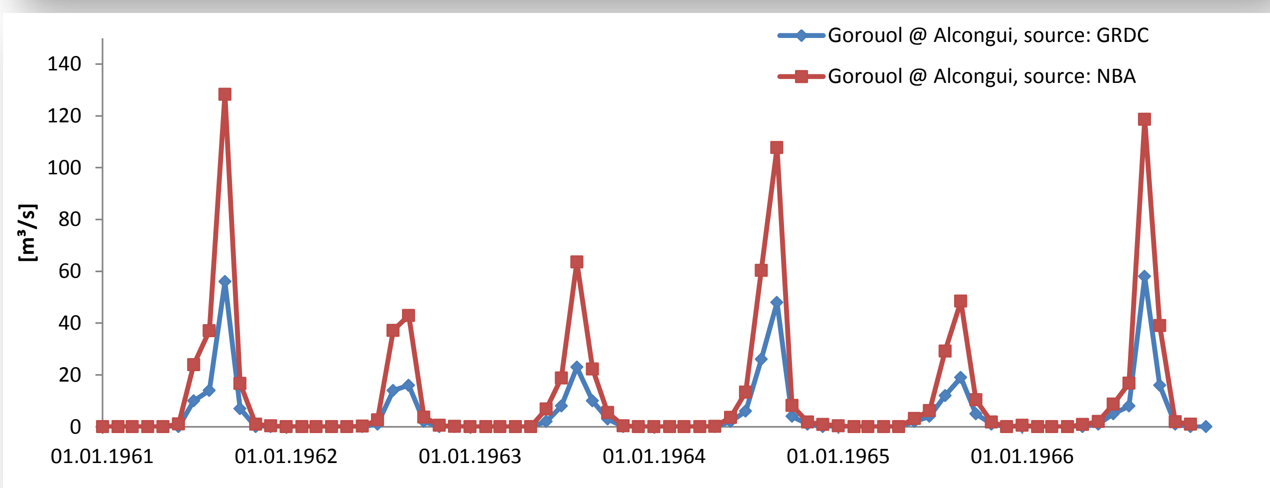
	Valeurs moyennes mensuelles (m3/s)												
Année	**Jan**	**Fev**	**Mar**	**Avr**	**Mai**	**Jun**	**Jul**	**Aou**	**Sep**	**Oct**	**Nov**	**Dec**	**Annuel**
1964		(10.84)	19.75	63.34	(86.98)	(96.5)	195.08	233.61	(271.37)	(291.51)	(114.46)	52.98	(148.52)
1965	28.18	69.65	28.03	47.91	60.67	137.24	259.92	256.6	290.8	212.9	85.62	31.08	126.02
1966	19.35	19.53	19.71	19.9	20.09	20.28	20.46	20.66	20.84	21.03	21.22	21.41	20.38
1967	21.92	13.55	13.24	48.57	102.04	100.66	255.55	273.39		(342.73)	256.73	42.23	(135.16)
1968	23.14	23.9	24.66	25.43	26.2	26.98	27.75	28.53	29.3	30.08	30.85	31.62	27.38
1969	(18.8)	13.55			(97.53)	100.79	258.63	269.55	276.68	235.5	92.78	(47.58)	(152.8)
1970	(23.99)	(18.68)	(21.07)	(26.82)	66.38	98.77	149.11	197.4	201.88	180.44	101.42	36.37	(103.02)
1971	(21.54)	(25.22)	30.06	40.47	43	79.04	207.37	185.38		(198.87)	65.79	33.21	(93.66)
1972	(22.12)		(17.91)	27.68	56.71	112.89	161.68	200.67	212.1	165.04	74.97	30.46	(108.24)
1973	(27.07)	(13.2)	15.57	25.7	48.86	62.77	98.47	143.35	189.42	135.64	75.52		(84.19)
1974	18.01	11.92	12.56	42.74	42.72	102.94	180.27	196.16	233.18	214.67	123.35	46.13	102.54
1975	23.86	(21.39)	(29.73)	45.45	51.01	83.42	142.56	155.53	233.41	239.34	95.34	47.58	(104.4)
1976	24.32	24.75	35.05	52.69	50.47	81.39	187.99	227.34	238.23	221.12	129.88	48.97	110.48
1977	27.05	(18.53)	(9.26)	16.43	41.26	99.92	208.15	188.11	251.38	197.38	69	31.02	(107.24)
1978	18.49	12.37	20.1	47	44.08	123.15	177.52	207.9	237.07	206.31	94.06	38.4	102.69
1979	20.58	15.86	18.9	28.49	67.17	115.4	192.46	263.86	194.78	172.8	(147.18)		(120.47)
1980	(20.19)	13.53	16.37	23.91	78.85	110.58	136.65	211.26	239.49	199.92	100.58	42.2	(103.69)
1981	30.87	30.78	30.7	30.62	30.54	30.45	30.37	30.28	30.2	30.12	30.03	29.95	30.41
1982	29.87	29.78	29.7	29.62	29.54	29.45	29.37	29.28	29.2	29.12	29.03	28.95	29.41
1983	28.87	28.78	28.7	28.62	28.54	28.45	28.37	28.28	28.2	28.12	28.03	27.95	28.41
1984	27.87	27.78	27.7	27.62	27.53	27.45	27.37	27.28	27.2	27.12	27.03	26.95	27.41
1985	26.86	26.78	26.7	26.62	26.53	26.45	26.37	26.28	26.2	26.12	26.03	25.95	26.41
1986	25.86	25.78	25.7	25.62	25.53	25.45	25.37	25.28	25.2	25.12	25.03	24.95	25.41
1987	24.86	24.78	24.7	24.62	24.53	24.45	24.37	24.28	24.2	24.12	24.03	23.95	24.41
1988	23.86	23.78	23.7	23.62	23.53	23.45	23.37	23.28	23.2	23.11	23.03	22.95	23.41

data source: NBA

Data quality

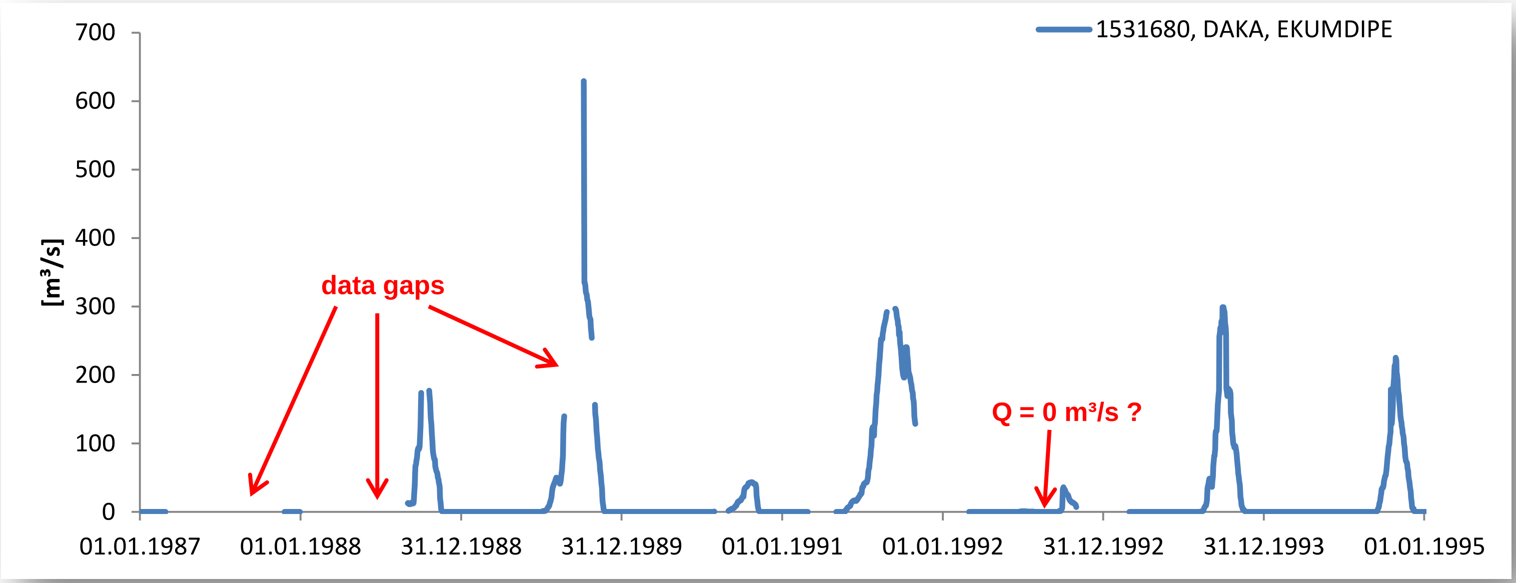
Questionable discharge data at some gauges





Data quality

Example for data gaps



“Observed” discharge data have to be treated with caution!

Pre-processing of observed discharge data

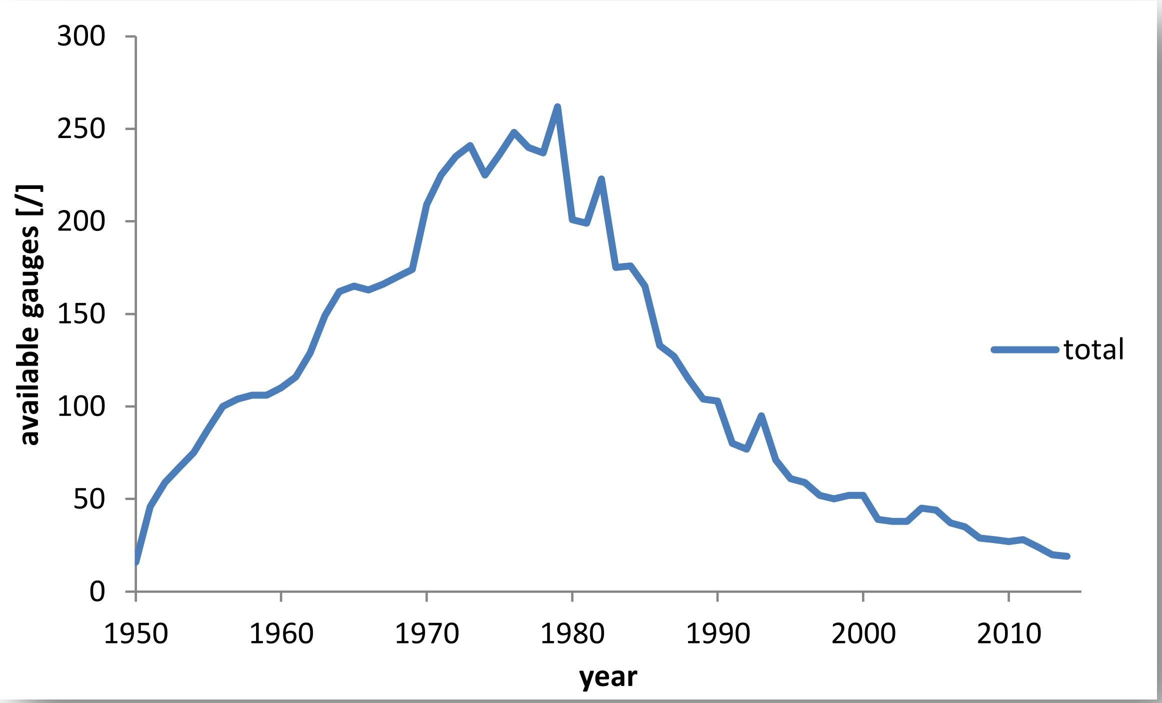
Gap-filling (yellow shading)

RIVER	MAGOU	MONO	OUEME	ZOU	OUEME	OKPARA	ZOU	OUEME	OUEME	SO	MEKROU	ALIBORI	MEKROU
STATION	TIELE	ATHIEME	PONT DE E	ATCHERIG	PONT DE S	KABOUA	DOME	SAGON	BONOU	SO-AWA	KOMPON(	ROUTE KA	BAROU
COUNTRY	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ	BJ
SOURCE	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC	GRDC
01.09.1966	15	587	139	43	363	90	48	477	582	97	61	164	105
01.10.1966	26	500	178	20	325	106	18	439	512	94	87	77	103
01.11.1966	1	150	23	5	64	30	9	161	153	59	20	5	30
01.12.1966	0	7	1	0	4	2	1	25	27	34	4	0	2
01.01.1967	0	2	0	0	0	0	0	4	5	29	0	0	0
01.02.1967	0	1	0	0	0	0	0	2	3	32	0	0	0
01.03.1967	0	2	0	6	0	0	4	1	4	35	0	0	0
01.04.1967	0	4	0	4	1	0	6	5	9	38	0	0	0
01.05.1967	0	7	0	2	0	0	3	5	7	37	0	2	0
01.06.1967	0	20	1	17	2	0	21	20	29	35	0	5	0
01.07.1967	0	100	44	13	72	0	21	85	60	30	3	19	5
01.08.1967	10	487	249	79	516	28	76	459	483	48	79	106	64
01.09.1967	30	659	348	67	767	123	68	796	846	128	162.07	302	219
01.10.1967	12	396	216	22	421	140	26	628	750	175	87	105	168
01.11.1967	0	100	21	2	46	24	3	124	142	63	20	5	24
01.12.1967	0	20	3	0	8	2	0	15	20	33	6	1	6
01.01.1968	0	10	1	0	1	0	0	5	6	33	1	0	1
01.02.1968	0	5	0	0	0	0	0	1	2	34	0	0	0
01.03.1968	0	1	0	0	0	0	0	1	2	39	0	0	0
01.04.1968	0	1	1	0	1	0	1	1	2	34	0	0	0
01.05.1968	0	4	3	3	5	0	4	10	13	39	0	3	1
01.06.1968	0	50	35	16	62	3	24	50	69	45	3	9	14
01.07.1968	8	601	198	252	303	30	122	355	540	95	54	89	27
01.08.1968	24	800	264	343	550	143	129	763	982	197	123	140	110
01.09.1968	25	756	384	345	907	359	126	928	1076	248	160.57	133	186
01.10.1968	19	300	180	150	429	187	114	800	948	216	93	64	113
01.11.1968	0	60	14	9	63	30	39	250	292	100	18	8	24
01.12.1968	0	10	3	0	6	3	3	30	40	42	2	1	7
01.01.1969	0	1	0	0	0	0	2	10	12	37	0	0	2
01.02.1969	0	1	0	0	0	0	1	4	6	38	0	0	0
01.03.1969	0	1	0	0	0	0	1	3	5	46	0	0	0
01.04.1969	0	7	0	2	0	0	2	5	7	41	0.01	0	0

- Discharge data of all 410 gauges were manually checked. Implausible data removed.
- Manual gap-filling of monthly data to enable computation of annual means.
- At gauges in semi-arid regions often missing records in dry season. Staff gauge readings only during wet season.

Observed discharge data

Availability of annual data at 410 gauges after pre-processing



- Implausible data removed
- Filling of short data gaps

Precipitation data in Africa

Data sources

- Individual station measurements
  - Data collection, gap filling, spatial mapping would require huge work effort
  - Not considered in this study

- Gridded station based data
  - GPCC: Global Precipitation Climatology Centre

- Satellite based data
  - TRMM: Tropical Rainfall Measuring Mission
    - TRMM 3B42: “High” quality product, “corrected” with ground measurements
    - TRMM 3B42RT: Real-time product, no ground measurements
  - RFE Africa: Rainfall Estimator (FEWS-NET,)

- Various other products not considered
  - GTS CPC
  - RFE ARC

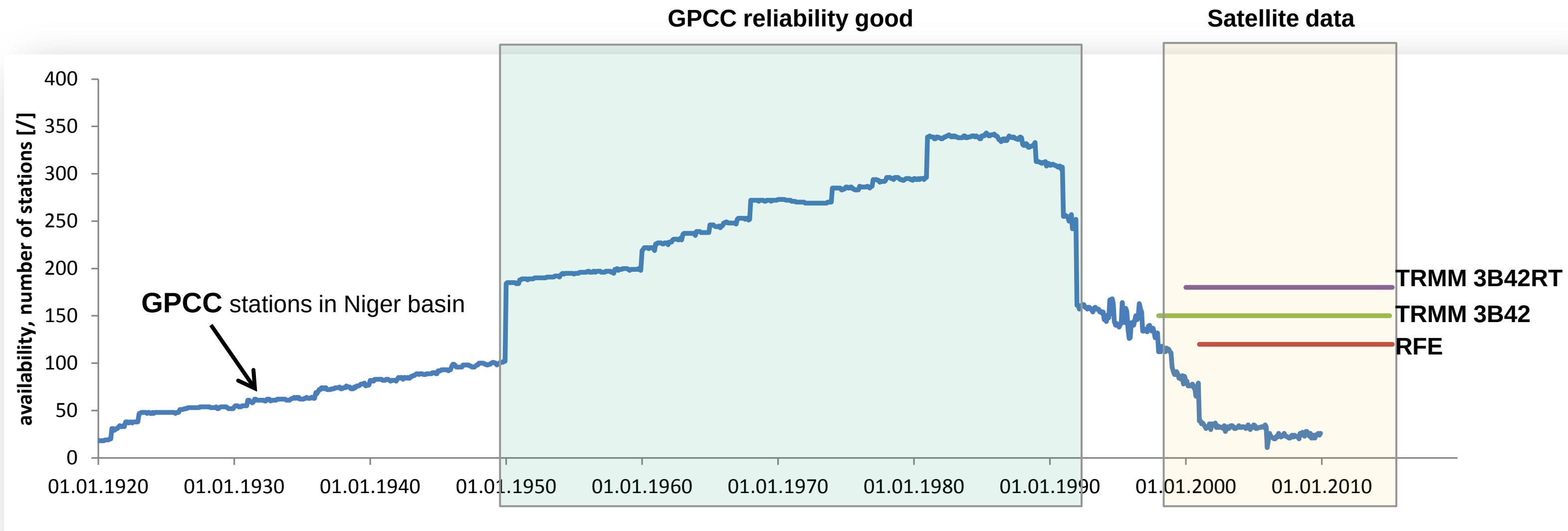
Precipitation data

Spatial and temporal resolution

Product	Spatial resolution	Temporal resolution	Availability	Comments
GPCC	0.5 x 0.5 °	monthly	1901 – 2009	Coarse resolution, best reliability (especially 1950-1990)
TRMM 3B42	0.25 x 0.25 °	daily	1998 – 2014	
TRMM 3B42RT	0.25 x 0.25 °	daily (3h)	2000 – now	Real-time product.
RFE Africa	0.1 x 0.1 °	daily	2001 – now	Finest resolution, quality problems in some regions

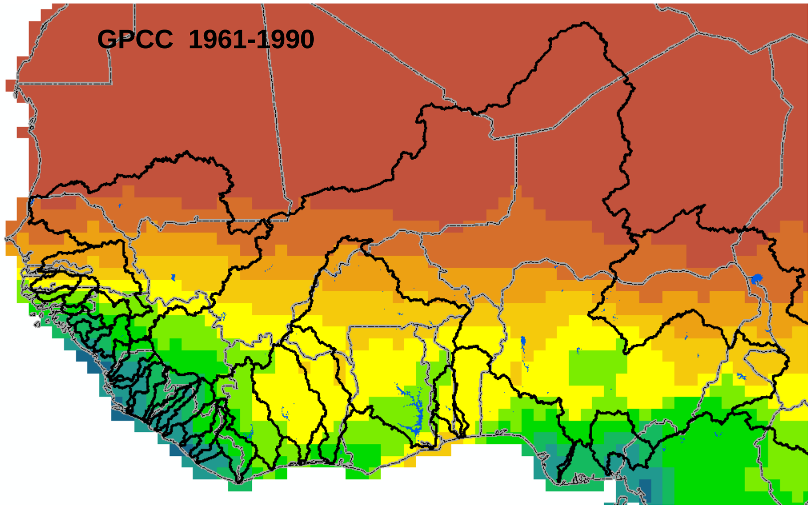
Availability of precipitation data

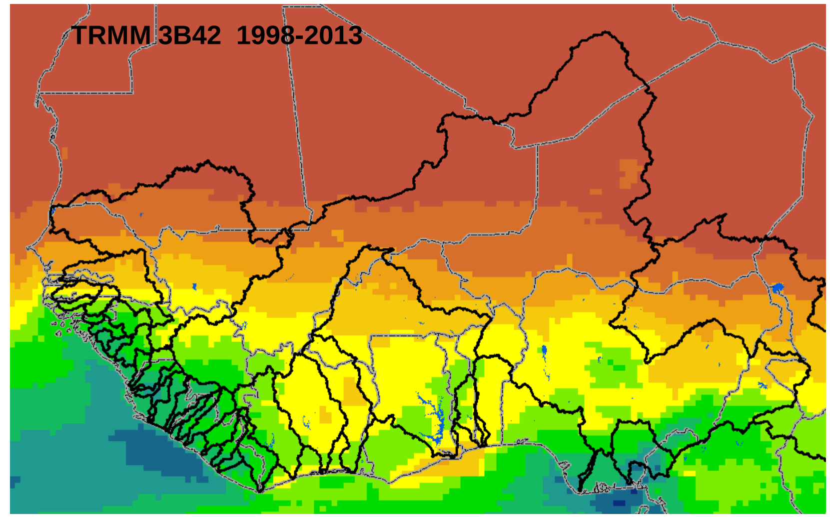
Period coverage

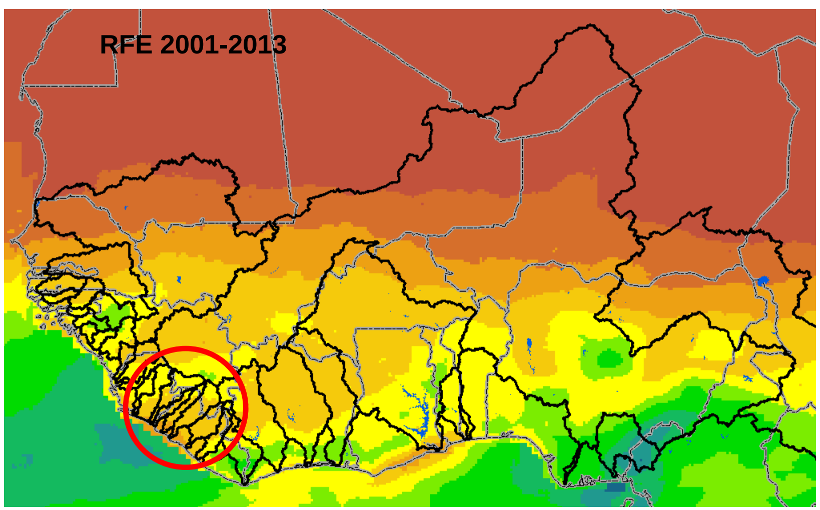


Annual precipitation

Long-term average of different products







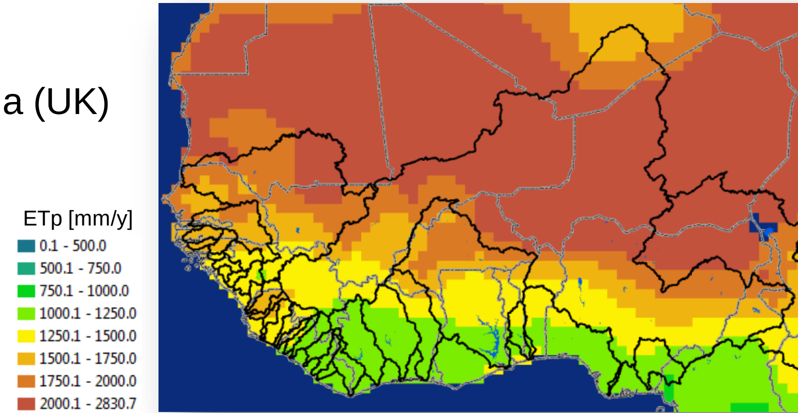
Precip [mm/y]

- 0.1 - 250
- 250.1 - 500
- 500.1 - 750
- 750.1 - 1,000
- 1,000.1 - 1,250
- 1,250.1 - 1,500
- 1,500.1 - 2,000
- 2,000.1 - 2,500
- 2,500.1 - 3,000
- 3,000.1 - 4,000
- 4,000.1 - 12,000

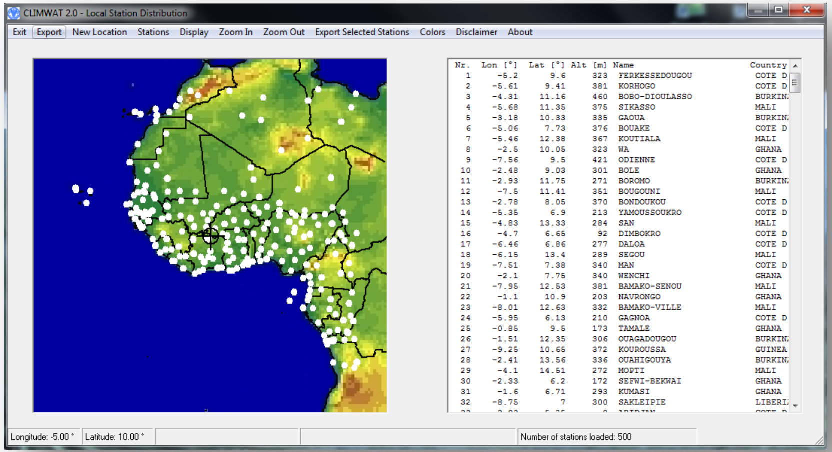
Potential evapotranspiration

Data sources

- CRU
  - Climate Research Unit: University of East Anglia (UK)
  - Monthly global grids 1901-2009
  - Penman-Monteith method
  - Air temperature also available

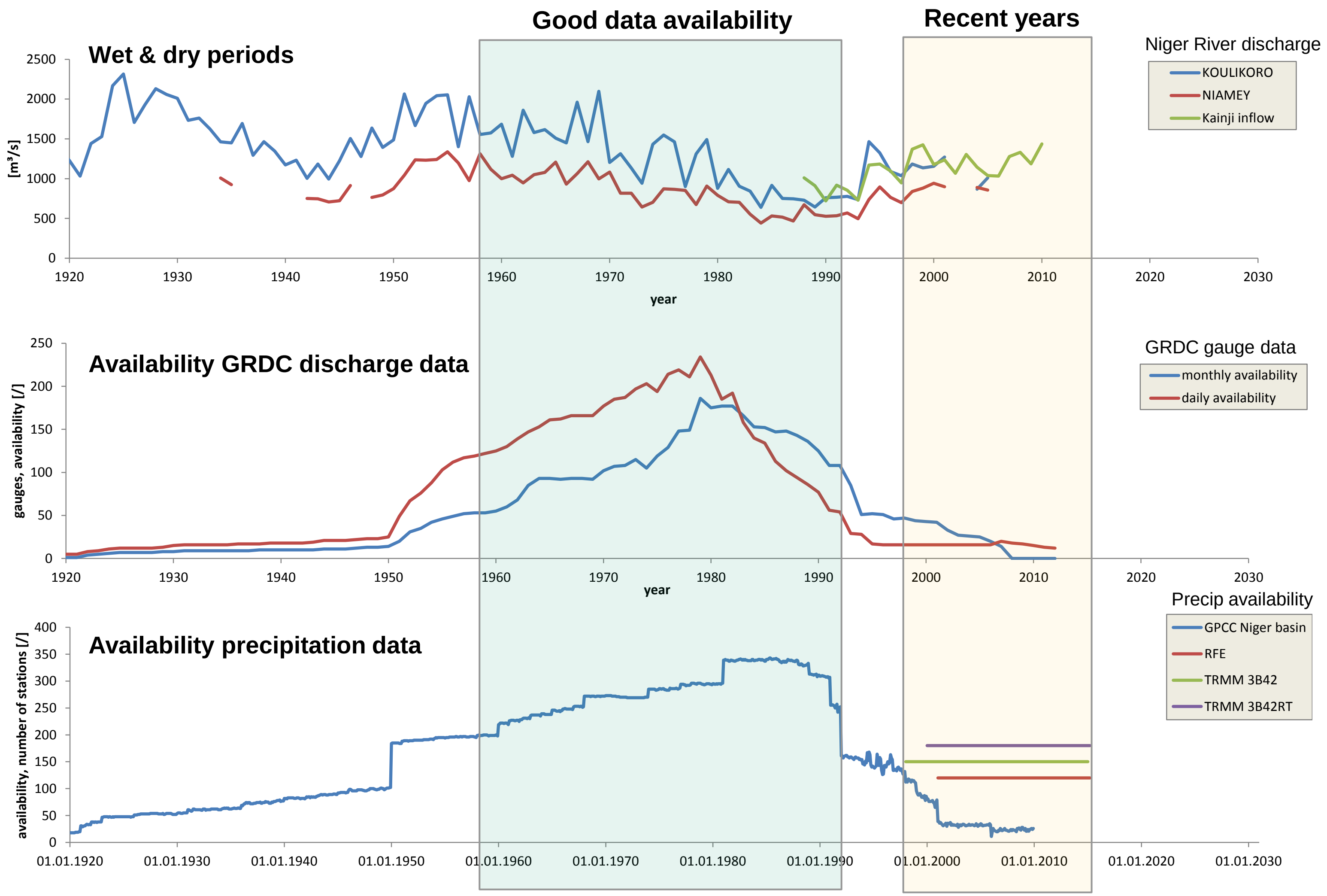


- CROPWAT & CLIMWAT
  - provided by FAO
  - Station based
  - Long-term monthly averages
  - Penman-Monteith method



Definition of common reference period

Data sources & availability



Definition of common reference period

- General considerations
  - Should be long enough to smooth out variability of individual years.
  - Should be well accepted by stakeholders.
  - Should have good data availability / reliability.
- 1961-1990 → **Calibration of water balance model.**
  - Good availability of observed discharge data.
  - High number of stations available for GPCC precipitation data.
  - Includes prolonged drought of the 1980s.
  - 1990 was 26 years ago, acceptance by stakeholders?
- 1998-2014 → **Adopted reference period for final results.**
  - Poor data availability for observed discharge data.
  - GPCC preciptiation data not reliable / available.
  - Satellite precipitation data available.
  - Since 1998 relatively stable meteorological conditions (moderately wet compared to last 100 years).

Data processing

Software issues

- **Standard GIS software ArcGIS 9.2, 10.0, QGIS**

  Used extensively in this study.

  Frequently crashed during processing (overflow of data).

  Ancient ArcView 3.1 more stable for some tasks.

- **Advanced data analysis / modelling**

  Higher performance (faster, no crashes) with tools outside GIS.

  gdal, shell scripts, python (slow), Fortran (fast), cdo

  Good programming skills required.

- **Meteorological data**

  GPCC, TRMM, RFE, climate model data in specific formats (ASCII, binary, NetCDF)

  Processing of time-series in GIS is not feasible.

  Instead use Fortran, cdo, etc.

Lessons learned

- Correct geo-referencing is highly time consuming due to lack of accurate information.
  - 410 discharge gauges
  - 91 existing hydropower plants

- Observed discharge data:
  - Several gauges appear to be affected by severe bias, especially after 1990. Outdated rating curve?
  - Gap filling is highly time consuming, but required to enable computation of annual means.

- There are large differences in meteorological data sets
  - Precipitation: GPCC & TRMM vs. RFE
  - Potential evapotranspiration: CRU, E2O, Climwat

- The period 1961-1990 has best data availability, but includes drought of 1980s. 1998-2014 is a better reference period for assessing the “current” hydropower potential.

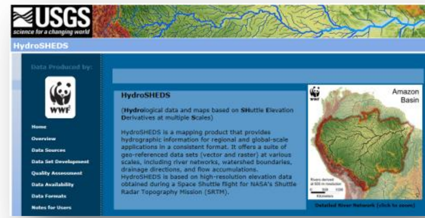
- Implementation of water balance model in GIS failed, due to too slow computation time. Alternative Fortran model enabled fast execution required for:
  - Time-series simulation
  - Model calibration (many repeated model runs)
  - Climate change simulations (60 model runs)

Lessons learned

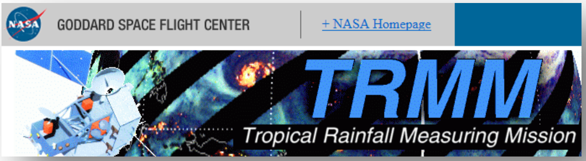
**Many datasets available.
Use them!**

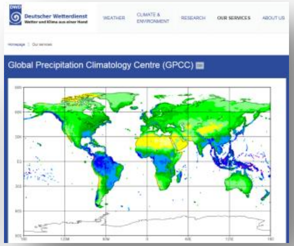
Very valuable data

- Hydrosheds
  - Flow direction grids
  - Digital elevation model (unconditioned)

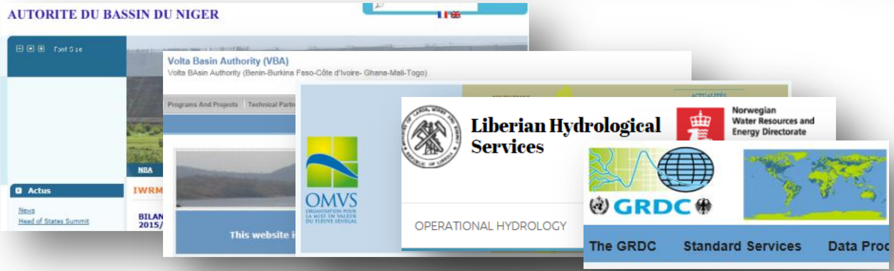


- Rainfall data
  - Tropical Rainfall Measuring Mission (TRMM)
  - Global Precipitation Climatology Center (GPCC)





- Discharge data
  - River Basin Organizations
  - National Hydrological Services
  - Global Runoff Data Center (GRDC)



- Gauge readers
  - Without them we would not have field information!

Group discussion

Data challenges in your country

- What are the key challenges for hydro-meteorological data in your country?
  - Sufficient funding for continuous field measurements?
  - Institutional challenges?
  - Personal experience?

- Data sharing policy?
  - Whom to contact to obtain observed discharge data?
  - Are data free or is a service charge required?
  - How fast are the data delivered?
  - Online data repositories?

- Reliability of data?
  - Sufficient number of rainfall stations?
  - Sufficient number of streamflow gauges?
  - How often are streamflow rating curves updated?

- Are global datasets used in your country?
  - Rainfall: GPCC, TRMM, RFE
  - Discharge: GRDC

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