Estimation and Mapping of Land surface temperature from AATSR images and GIS: A case study in Kolondieba-Tiendaga basin in Sudano-Sahelian climate, Mali

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Outline

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- ✓ Study Area
- ✓ Data & Method
- ✓ Results
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Introduction

- Strong climatic variability (rainfall deficit of 20-25%) since the year 1970

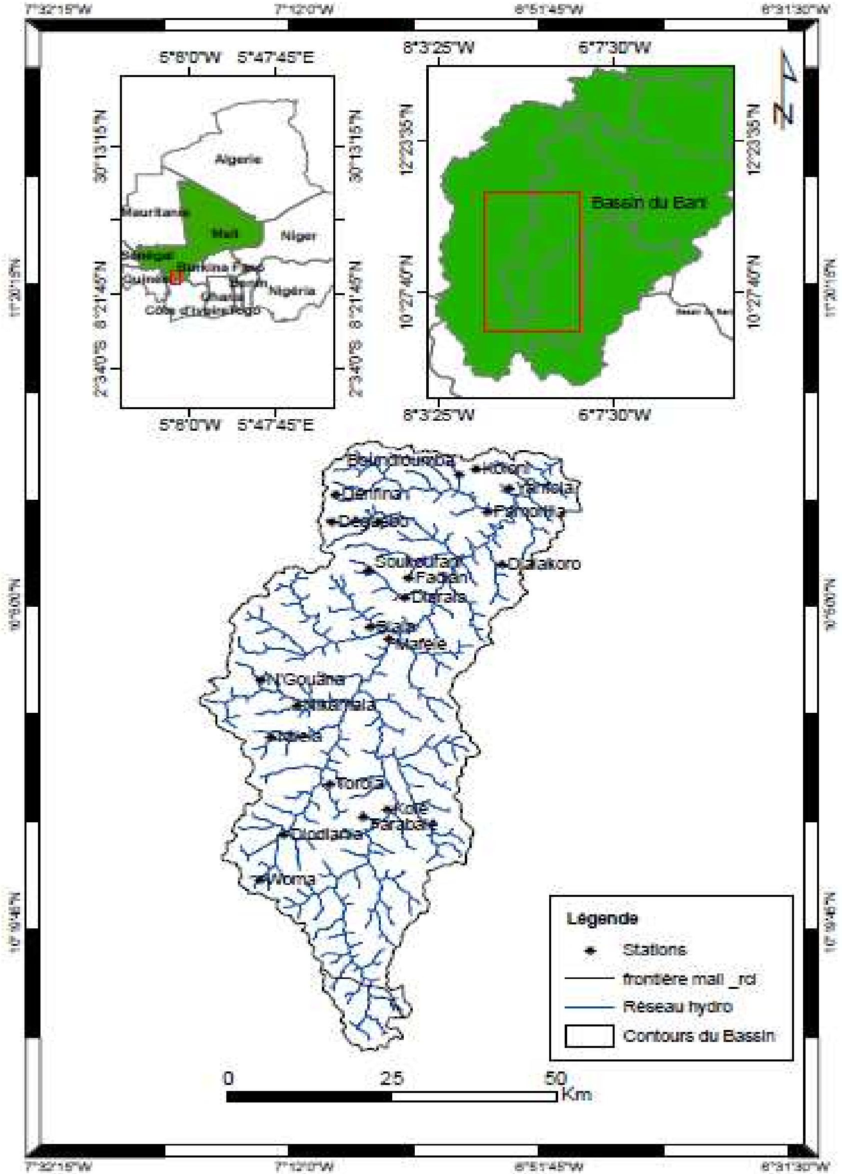
- LST is an important parameter in the energy balance and play an essential part in the processes of interaction between the Biosphere- hydrosphere-Atmosphere and the cycle of water (Gupta et al., 1997 ; Kant and Badarinath, 2000 ; Zhang et al., 2007)

- A key parameter in a wide range of environmental applications, such as :
  - hydrological (groundwater and surface interaction), meteorological, climatologically studies, and vegetation monitoring (Guillevic and al., 2012)
  - irrigation need estimates (Brasa-Ramos et al., 1998),
  - Forest fire risk forecasting, detection and monitoring (Briess et al., 2003),
  - air temperature and humidity determination (Florio et al., 2004; Vogt et al., 1997),
  - desertification, deforestation and climate change monitoring (Allen et al., 1994; Lambin & Ehrlich, 1997)….

Object

to estimate and mapping the land surface temperature using images AATSR over the period of 2003 to 2010,

Study area



watershed of Kolondièba-Tiendaga located in southern Mali

Longitudes: 7.34 °W and 6. 82°W

Latitudes: 10.15°N and 11.08°N

Surface : 3050 km²,

Climate South Sudan climate, characterized by the alternation of a warm and dry season (November-April) and of a rainy season (May-October)

Rain: 900 and 1200mm / year

Temperature : The monthly average temperatures vary between 38° (May) and 23 ° December);

Humidity: 82 % in August and 38 % in February;

Evapotranspiration: remain important, with a climax in May 161 mm (DNH-Mali, 1990);

Geology: metamorphic and granitic rocks covered with washed tropical ferruginous, ferralitic and hydromorphous soil

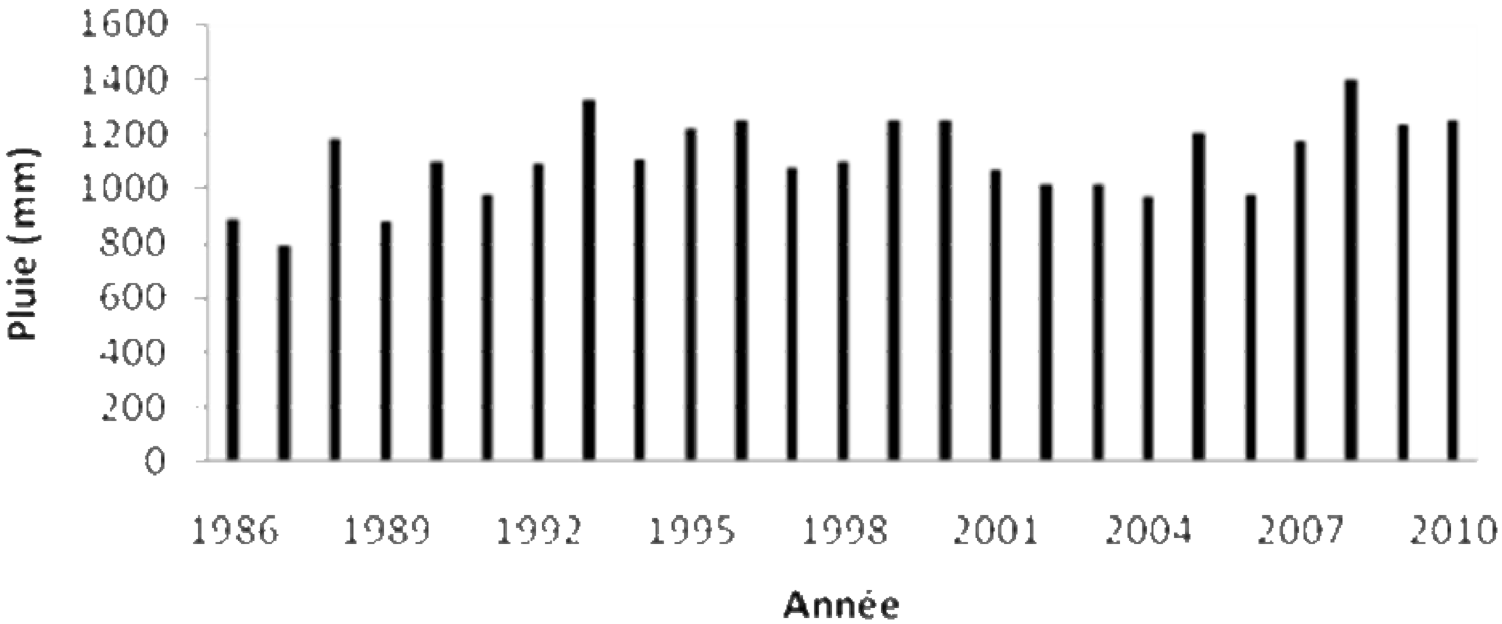
Relief: altitude vary between 315 and 390 m;

Vegetation: characterized by trees, shrubs, meadow, mixed up with annual agricultures.

Study area (Cd)

Designation	**Value**
Exutoire	Longitudes :11.066761 Latitudes : 6.846652
Altitude exutoire	313 m
Bassin surface	3050 Km^2
Main canal's lenght	158.30
Hydromorphic Network total lenght	5854.26
Ordre Strahler	7
Drainage density	1.895km/Km^2
Perimeter	430 Km
Indice of compactness	2.050 KG
Equivalent rectangle lenght	186 m
Equivalent rectangle largeness	16m

Study area (cd)



Annual rainfalls recorded on the versant basin of Kolondièba-Tiendaga between 1986 and 2010

Data & Method

Satellite data:

Advanced Along-Track Scanning Radiometer (AATSR) a sensor aboard ENVISAT launched since March 2002

ENVISAT satellite has **two different ways of observation**: the **nadir vision** and the observation with **a sloping angle of 55º** in front of the sub-satellite point at a distance of approximately 1000 km above the ground.

Spectral Band characteristics

Spectral band (µm)	Central wave lenght (µm)	Spectral region	Application
0.0545-0.565	0.555	visible	Chlorophylla
0.549-0.669	0.659	visible	Vegetation indication
0.855-0.875	0.865	infrared	Vegetation indication
1,580-1.640	1.61	infrared	Clean of claud
3.50-3.89	3.70	Mid-infrared	Temperature of sea surface
10.40-11.30	10.85	Thermal infrared	Temperature of sea surface
11.50-12.50	12.00	Thermal infrared	Temperature of sea surface

Radiometric Resolution : 12 bits

Spatial resolution: 1km

Meteorological data:

Temperature, wind speed, relative humidity (from National Direction of the Meteorology, Mali);
Solar radiation data used in this work are collected from Wagner (1998)

Data & Method

➢SEBS processor (Plugin) for BEAM

The algorithm in SEBS for retrieval of bio-geophysical parameters including surface albedo, temperature, and emissivity e.g. is briefly presented.

Reference height: Type a value for the reference height in meters.
Humidity: Type a value for the specific humidity at reference height in kg per kg.
Wind speed: Type a value for the wind speed at reference height in meters per second.
Temperature: Type a value for the air temperature at reference height in degree C.
Pressure: Type a value for the pressure at reference height in Pa.
Pressure at surface: Type a value for the pressure at surface in Pa.
Horizontal visibility: Type a value for the horizontal visibility in kilo meters.
Solar radiation: Select the solar radiation by typing in a value for the downward solar radiation, and turns the routine in SEBS to calculate the downward radiation value of.

➢Split-window Algorithm to extract LST

$$\mathbf{LST = T4 + 1.8(T4 - T5) + 48(1-\varepsilon) - 75\Delta\varepsilon}$$ Ulivieri et al 1994)

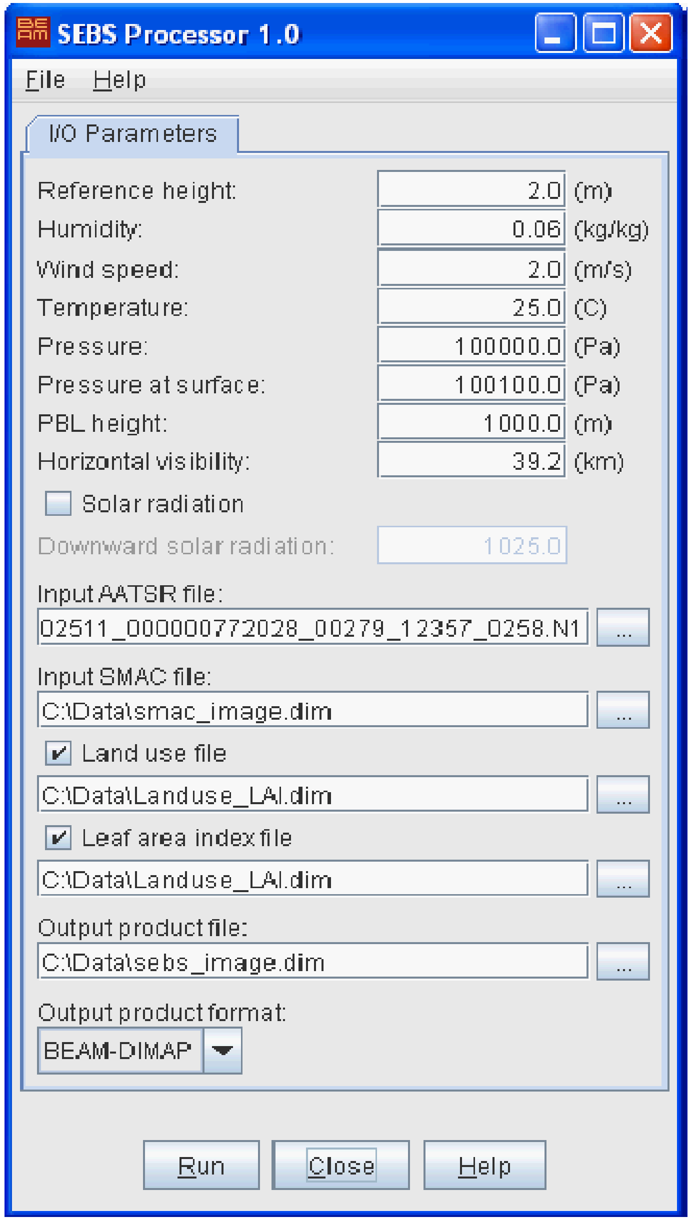
Where:

$T4$ = Channel 4 temperature (ºK)

$T5$ = Channel 5 temperature (ºK)

E= Average emissivity $(\varepsilon 4+ \varepsilon 5)/2$

$\Delta\varepsilon = \varepsilon 4 - \varepsilon 5$.



SEBS request value parameters

Data & Method

Estimation of the energy balance components

The image data and meteorological are used to calculate the surface heat flux.

The net radiation is divided into latent heat flux, sensitive heat flux and soil heat flux.

The latent heat flux (W/m2) is calculated according to the following equation:

where, $$LE = R_n - G - H$$

R_n is the net radiation (W/m^2)

G: the ground heat flux (W/m^2)

H: Sensitive heat flux (W/m^2)

R_n and G can be estimated locally by using meteorological data (Allen and al., 1998) and regionally by incorporation of emitted and thoughtful radiation distributed spatially (Jackson and al., 1985)

Net radiation R_n is given by the following formula: $R_n = R_{s\downarrow} - R_{s\uparrow} + R_{L\downarrow} - R_{L\uparrow}$ Where:

$R_{s\downarrow}$ Incident Shortwave radiation, coming from the sun

$R_{s\uparrow}$ Outgoing Shortwave radiation, coming from the land surface

$R_{L\downarrow}$ Downward Longwave radiation (> 4µm) resulting, emitted by atmosphere to ground

$R_{L\uparrow}$ Outgoing Longwave radiation (> 4µm) resulting, emitted land surface to space

The solar radiation absorbed by the surface of the soil is calculated according to the following relation: $R_{abs} = (1-\alpha)R_{s\downarrow}$ Where α is the albedo of surface

Data & Method (cd)

Estimation of the energy balance components (cd)

The Downward Longwave radiation is estimated on the basis of the measures of the soil and air temperature and the pressure of vapor by using the following relation:

$$R_{L\downarrow} = \varepsilon_a \sigma R_a^4$$

$$\varepsilon_a = 1.24\left(\frac{e_d}{T_a}\right)^{\frac{1}{7}}$$

Where, ε_a is the emissivity of the atmosphere

$\sigma = 5.67 * 10^{-8} w\ m^{-2} K^{-4}$ (constant of Stefan-Boltzmann)

T_a, the air temperature (°K) and

e_d is the deficit of pressure (mbar)

The Outgoing Longwave radiation is given by the following equation: $R_{L\uparrow} = \varepsilon_s \sigma T_s^4$

Where, : Surface emissivity can be, in the range of 8-14µm, predicted from the NDVI (Normalized Difference Vegetation Index) with a strong correlation according to following logarithmic relation: $\varepsilon_s = 1.0094 + 0.047 * \ln(NDVI)$ (Van de Giend and Owe, 1993),

T_s: the surface temperature in (°K).

The net radiation received by the surface is the sum of all incoming and outgoing radiations and is calculated according to the equation below: $R_n = (1-\alpha)R_{s\downarrow} - \varepsilon_a \sigma T_a^4 - \varepsilon_s T_s^4$

Data & Method

Soil heat flux (G) :

$$G = R_n \left(\frac{T_s}{\alpha}\right) * \left(0.0038\alpha + 0.0074\alpha^2\right) * \left(1 - 0.98 NDVI^4\right)$$

Sensitive heat flux : (H*)*

$$H = \rho C_p \left(T_s - T_a\right) / r_a \qquad r_a = 4.72\left\{\ln\left(z/z_0\right)\right\}^2 / \left(1 + 0.54u\right)$$

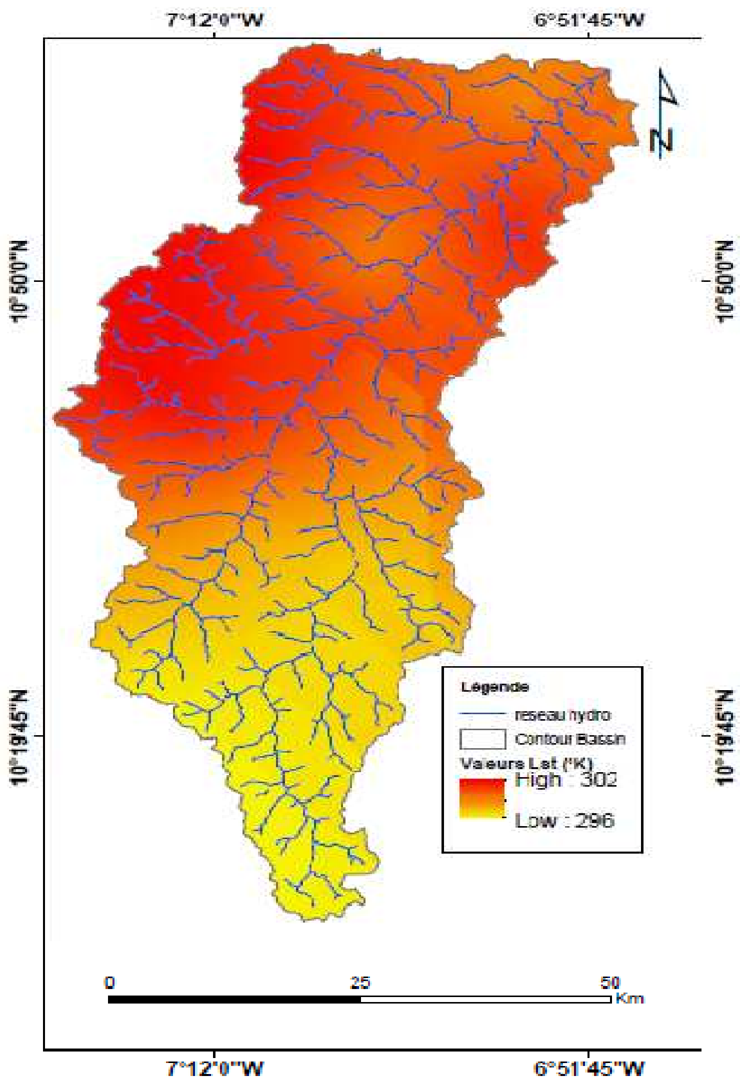
$$z_0 = \exp\left(0.01021 + 0.1484\left(NIR/Red\right)\right)$$

Results

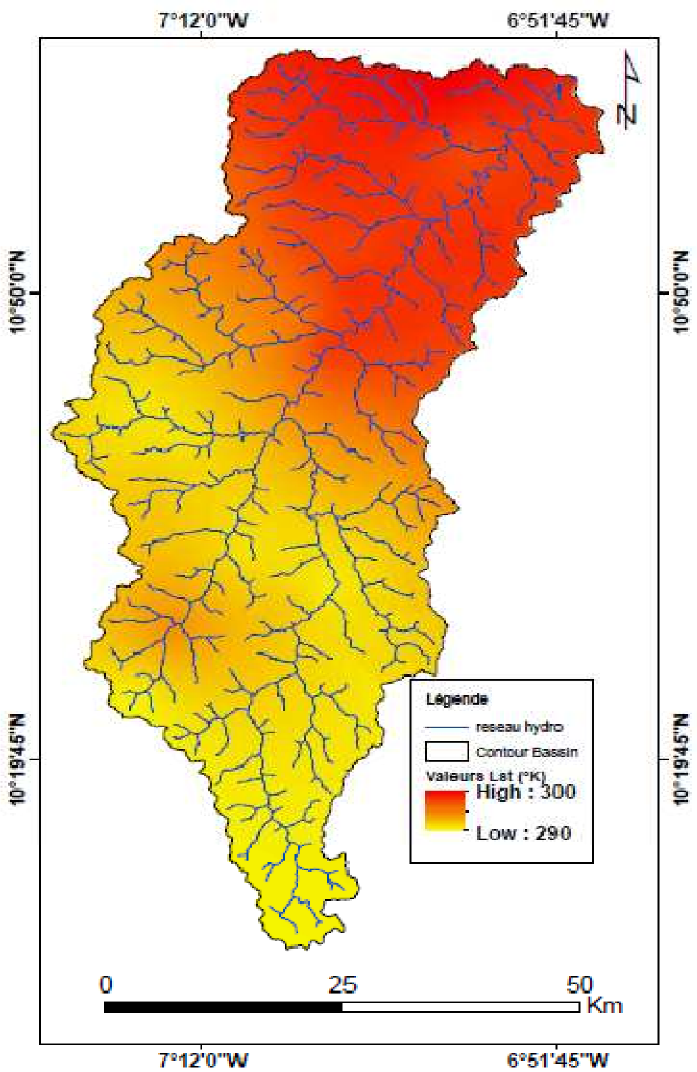
Stations	2003	2004	2005	2006	2007	2008	2009	2010	Moy	Max	Min	Ecart
1	296,92	293,17	295,10	298,94	295,39	295,67	291,48	290,96	294,70	298,94	290,96	2,70
2	299,06	294,13	294,58	296,14	297,29	295,22	291,65	294,81	295,36	299,06	291,65	2,21
3	298,57	296,31	296,23	295,59	296,69	295,66	292,68	292,51	295,53	298,57	292,51	2,03
4	297,57	297,77	297,72	296,02	298,86	296,18	292,63	291,16	295,99	298,86	291,16	2,71
5	298,19	298,25	297,82	296,69	296,61	295,67	295,83	291,59	296,33	298,25	291,59	2,16
6	299,84	297,61	298,42	296,94	295,35	292,90	296,71	292,66	296,30	299,84	292,66	2,54
7	302,50	297,45	297,24	295,40	295,23	296,04	298,56	291,57	296,75	302,50	291,57	3,13
8	301,92	297,18	296,03	293,49	293,61	295,17	296,80	291,49	295,71	301,92	291,49	3,15
9	301,80	298,62	298,16	297,15	295,89	296,14	291,88	298,10	297,22	301,80	291,88	2,83
10	300,69	296,12	298,82	298,82	297,31	294,84	290,88	295,70	296,65	300,69	290,88	3,02
11	298,52	296,31	299,52	299,13	297,95	295,58	292,61	298,47	297,26	299,52	292,61	2,31
12	298,23	294,65	297,64	297,83	300,01	293,58	293,69	297,69	296,66	300,01	293,58	2,37
13	299,73	296,44	298,67	299,73	300,48	295,92	294,05	297,59	297,83	300,48	294,05	2,23
14	302,80	295,44	298,51	295,30	300,59	295,72	290,76	298,66	297,22	302,80	290,76	3,72
16	301,28	296,39	298,02	299,48	300,00	294,44	290,12	298,65	297,30	301,28	290,12	3,60
15	302,83	295,89	296,83	297,24	302,20	294,22	290,46	296,75	297,05	302,83	290,46	4,02
18	300,63	291,70	295,36	299,37	300,76	294,36	288,54	297,36	296,01	300,76	288,54	4,38
17	301,56	293,89	298,74	293,33	298,94	294,44	290,94	297,84	296,21	301,56	290,94	3,58
19	298,19	291,50	298,25	295,17	301,29	293,76	288,88	298,76	295,73	301,29	288,88	4,17
20	299,87	293,94	298,65	295,49	303,49	295,60	291,63	299,88	297,32	303,49	291,63	3,83
21	299,30	293,48	297,47	294,78	301,05	296,09	289,97	300,26	296,55	301,05	289,97	3,75
Moy	300,00	295,54	297,51	296,76	298,52	295,10	292,42	295,83				
Max	302,83	298,62	299,52	299,73	303,49	296,18	298,56	299,88				
Min	296,92	291,50	294,58	293,33	293,61	292,90	288,54	290,96				
Ecart	1,80023	2,0569	1,35218	1,9491	2,666	0,9446	2,6806	3,23242				

Results

2003



2010



Conclusion and Prospects

today the remote sensing and GIS tools appear like an essential element in the collection and the cartography of the parameters biophysics on broad scales, of which in particular the evapotranspiration, the temperature of surface, emissivity, albedo, etc

The results of the study show temperature values ranging between 303 and 296 with standard deviation (2.66 and 0, 945). These results show a good trend with evapotranspiration calculated from the evaporative fraction.

- For a better validation of these results, it would be necessary to make measurements validation in-situ on the catchment area of kolondièba-Tiendaga.

- We could also use another model of assessment of energy in order to make a comparative analysis of the results obtained starting from the two models

- In end, it would be interesting to use this model with images of which the space resolution is finer, because the space resolution of images AATSR is of 1Km x1Km

Thank you for your Attention!!!!