Université de Liège - Faculté des Sciences Appliquées
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Université Cheikh Anta Diop de Dakar - Faculté des Sciences et Techniques/Département de Géologie -

Groundwater flow and saltwater intrusion modelling in the Continental Terminal (CT) aquifer near the Saloum inverse estuary in Senegal

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N° abstract: 1792

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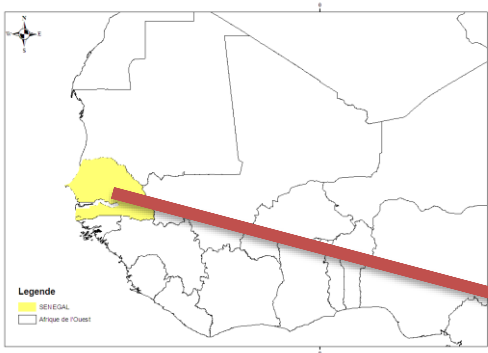
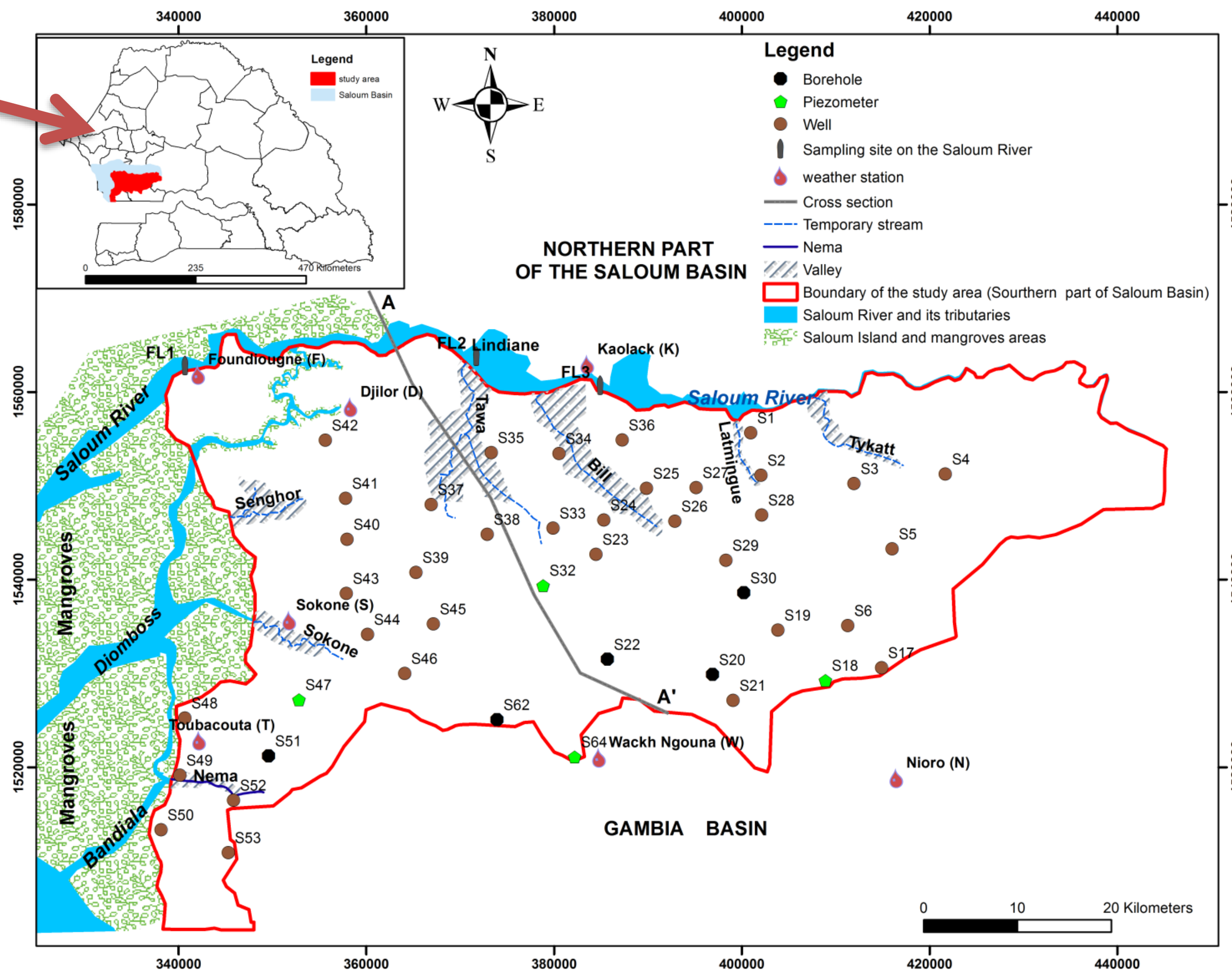
❑ Introduction: Location of study area



western part of Senegal (covers the southern part of the Saloum Basin except for the mangrove system.

It is limited in the:

- north by the Saloum River
- west by the mangrove area
- south and east by the Gambia River catchment

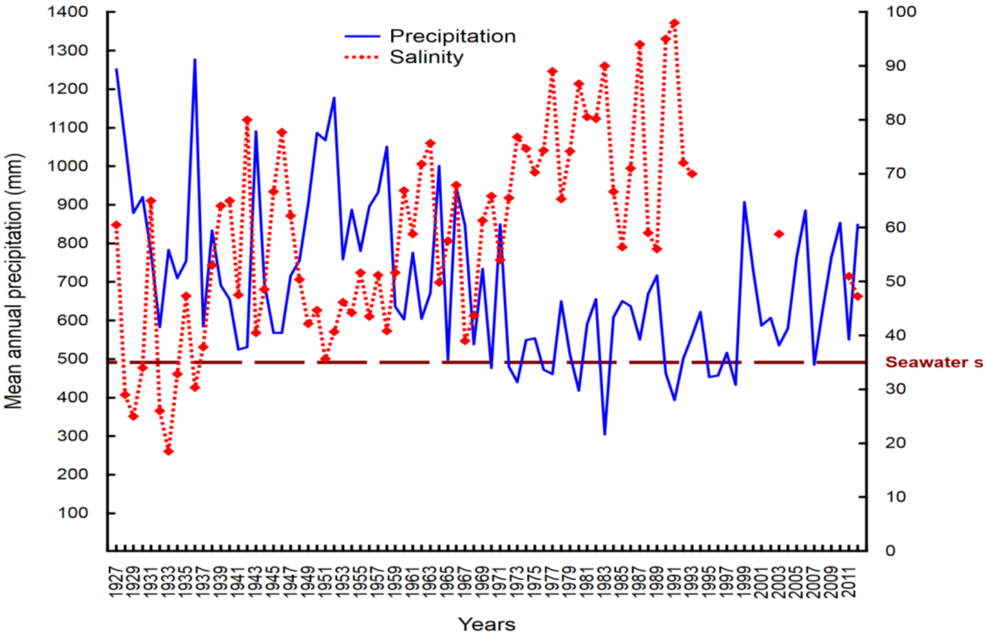


N°abstract

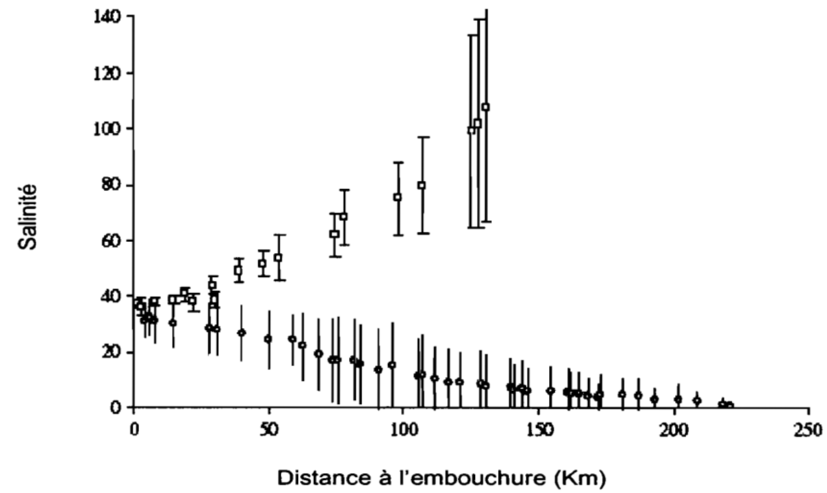
Introduction: Context

Increase in the average **temperatures, sea level rise** and **the decrease** of the **rainfall**
Low lying zone and **gentle slope**

→ **Increased salinity** → **Hypersaline estuary**



interannual variation of salinity and rainfall in Kaolack station from 1927 to 1985

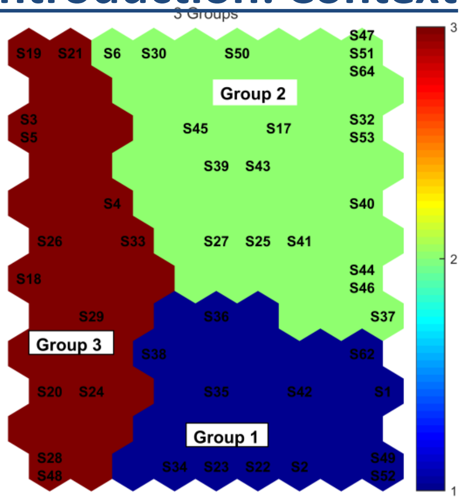


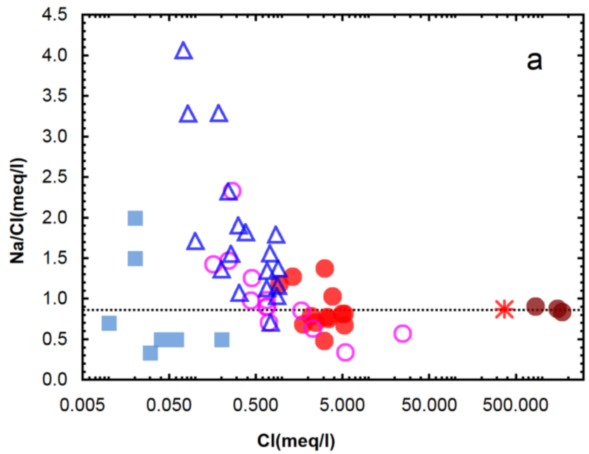
(Source: Panfili et al.2006)

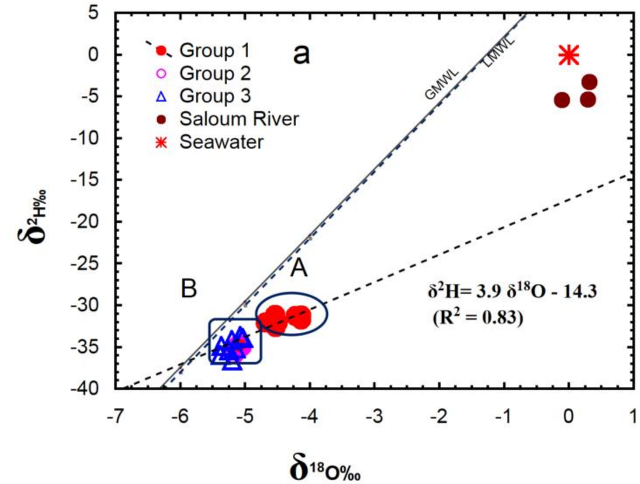
The Saloum River hypersaline estuary is an 'inverse estuary" showing a salinity increasing from the river mouth towards inland

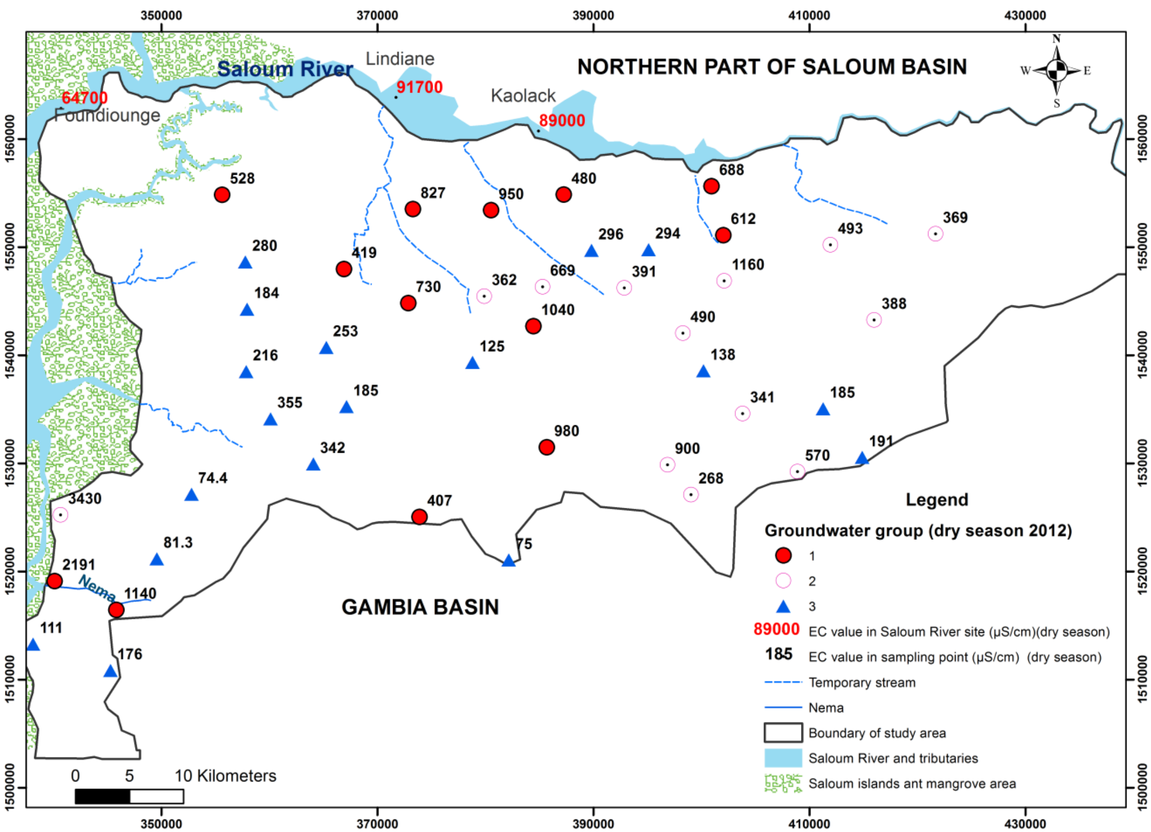
Consequences: Degradation of Mangrove, agricultural soils and water ressources

❑ Introduction: Context









Hydrochemical and multivariate analysis : Groundwater are threatened by saltwater intrusion from the ocean and from the Saloum River (Dieng et *al*, submitted)

It is a serious problem because in this region water supply rely only on this GW resource.

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❑ OBJECTIVES

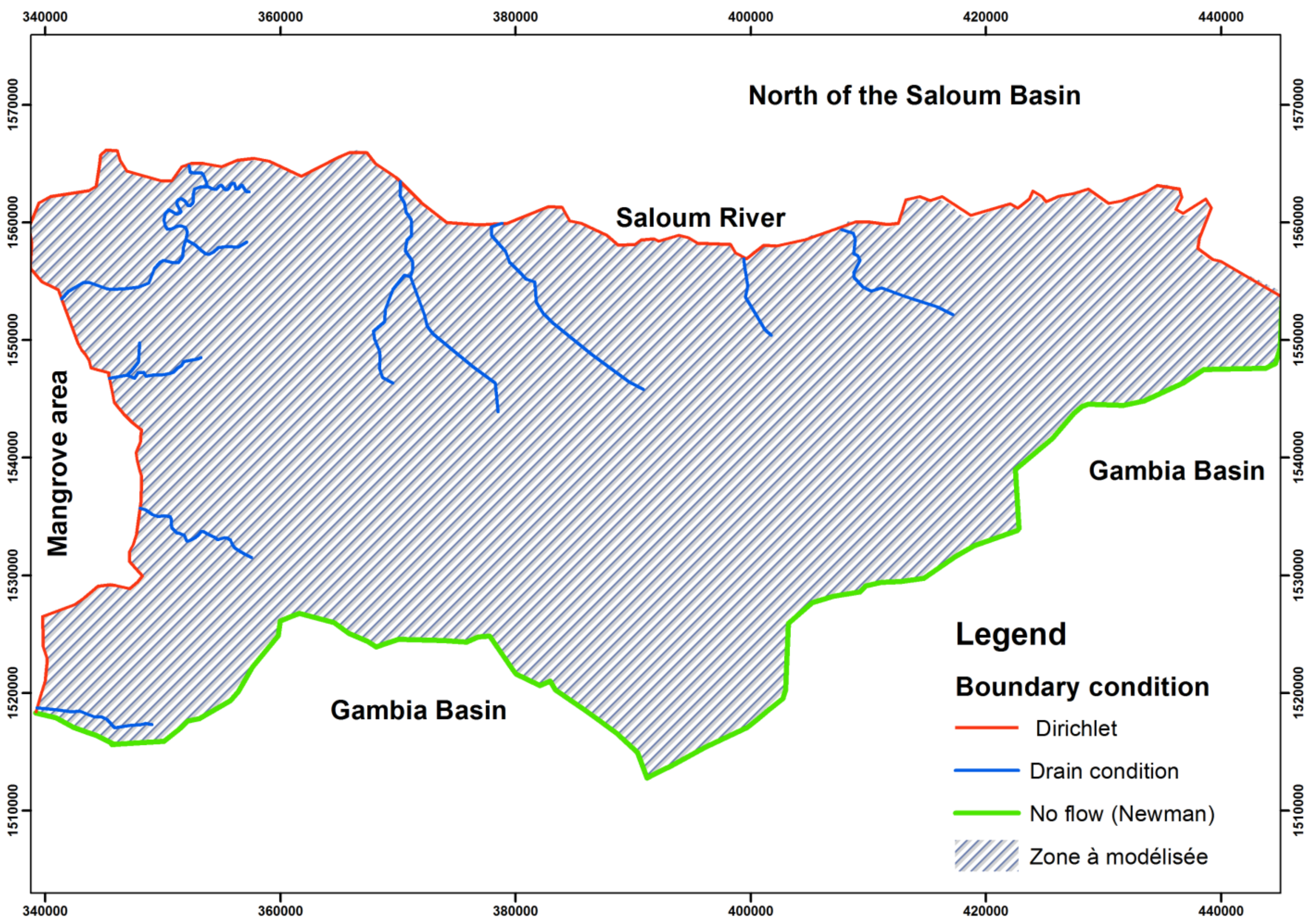
Overall objective

provide a better understanding about the relationship between the Saloum River and the groundwater

Specific objectives include

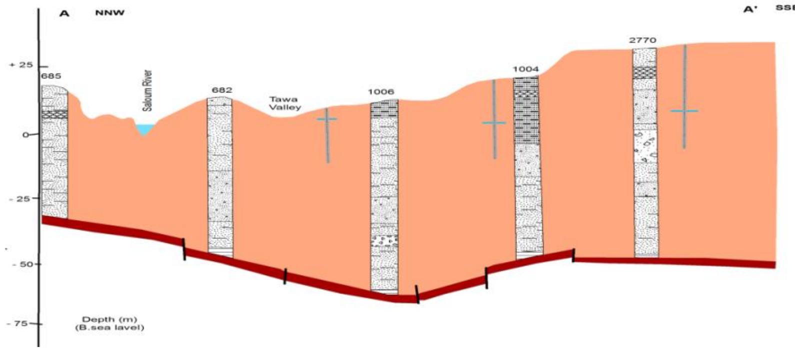
- synthesize and integrate existing data to better understand the hydrodynamic flow of the CT aquifer system and its relationship to the salty waters of the river;
- Evaluate water balance and fluxes exchanges between the Saloum river and groundwater;
- Infer salinization trend in the long term under various scenarios (pumping, climate change) that could affect the GW resources

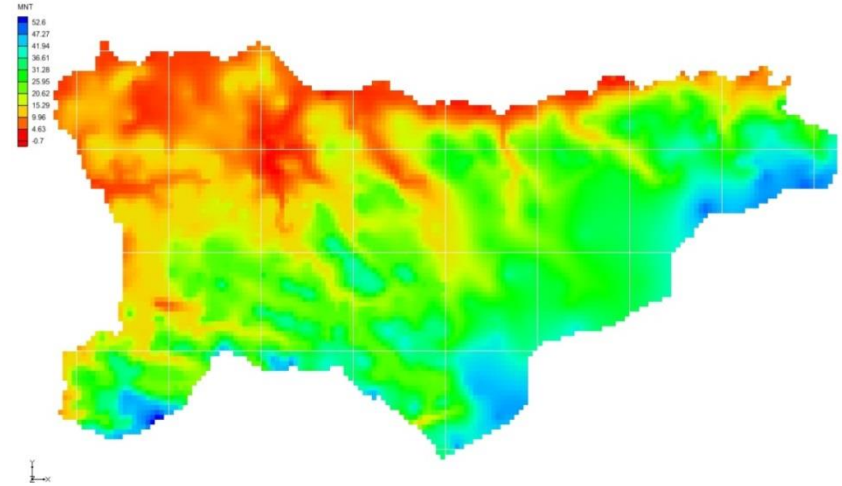
❑ Conceptual model *Model domain and flow boundary conditions*



- North (the Saloum River) and west (mangrove area): Dirichlet condition (constant head)
- south and east (hydrogeological boundary): Newman condition (no flow)
- Streams (receives a groundwater base flow): drain condition

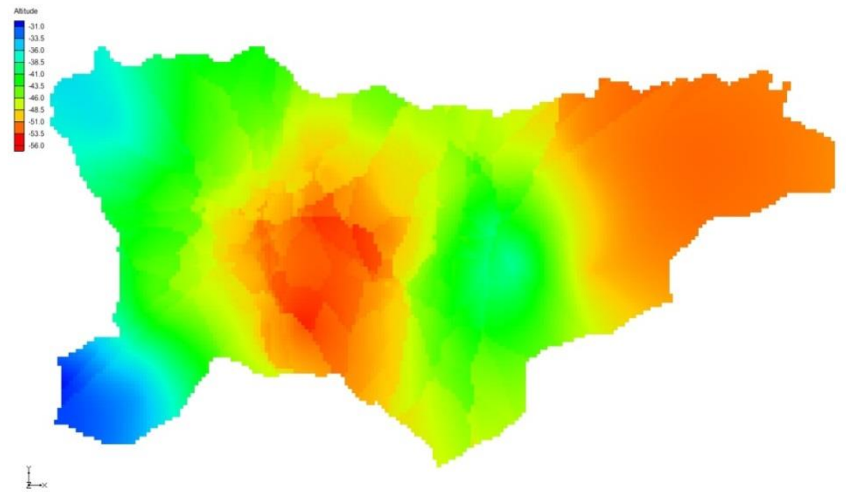
❑ Conceptual model: *Model discretization*





Spatial discretization

- Unconfined aquifer (laterally and vertically heterogeneous and contain discontinuous interbedded sandstone, sandy clay, clayey sand, silt and clay
- Top boundary (surface topography):DEM created from topographical map (1:50 000)
- Bottom boundary (marly or clayey bedrock (-30 et -60 m)
- One alyered (because lack of geological information)

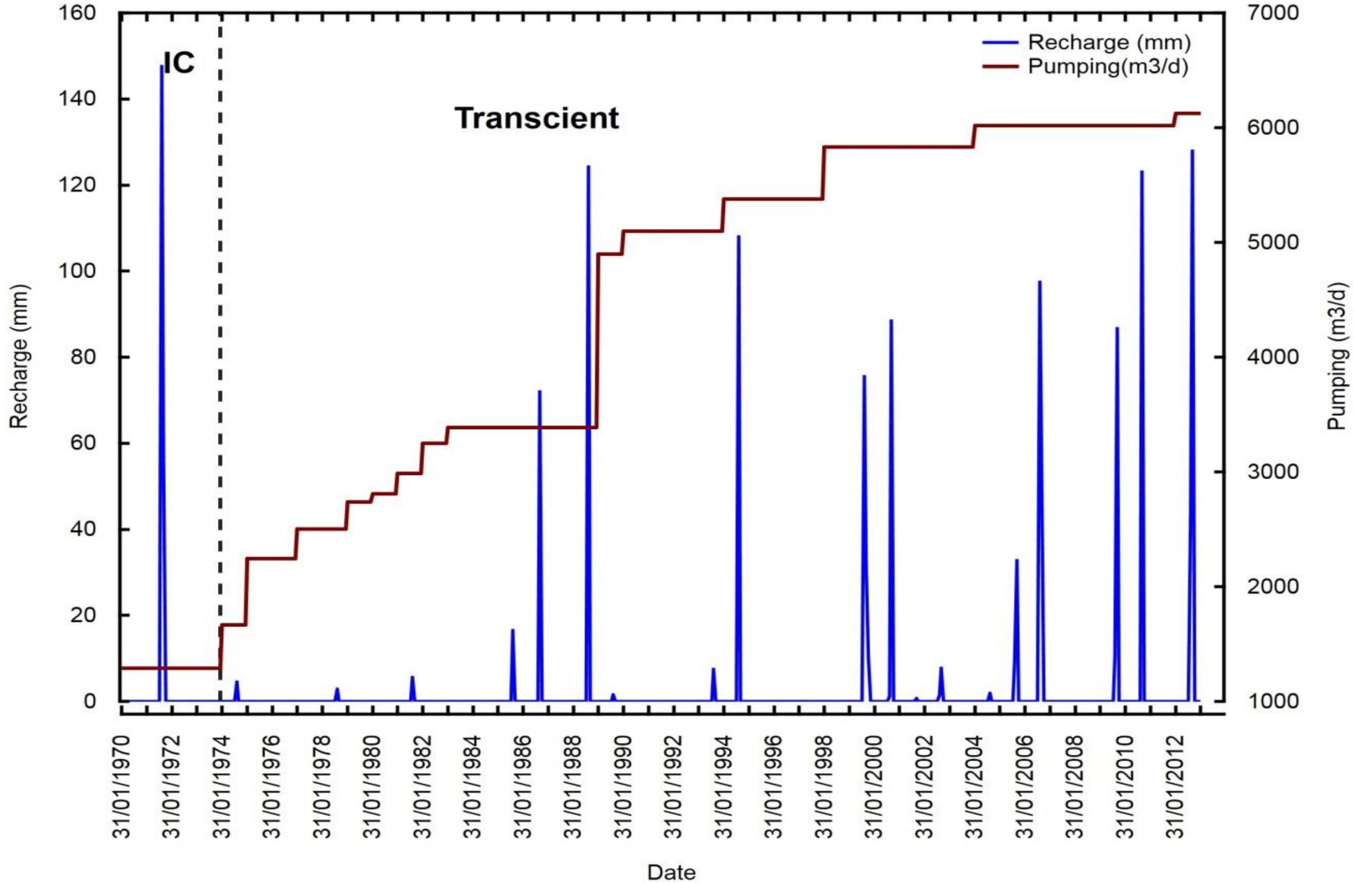


Recharge values

obtained from Thorntwaite's method

Hydraulic properties The initial hydraulic head of the domain was set according to the interpolation of the observation values

❑ Conceptual model: *Model discretization (temporel)*



Interpretation of temporal pumping rate evolution related to groundwater flow during the period 1970 to 2012.(*IC* :Initiale Condition/steaDy-state)

- Groundwater flow model is developed using MODFLOW code
- 2 D model (no vertical drainance
- Dimensions of basic cell: 250 m x 250 m
- grid of 218 rows and 409 columns

The model was calibrated to observed piezometric head.

- a preliminary calibration was performed in steady-state situation corresponding to the CT aquifer state in 1973 before development of pumping and results are used for initial condition for the transient simulation of the groundwater flow model performed on available data from 1974 to 2012

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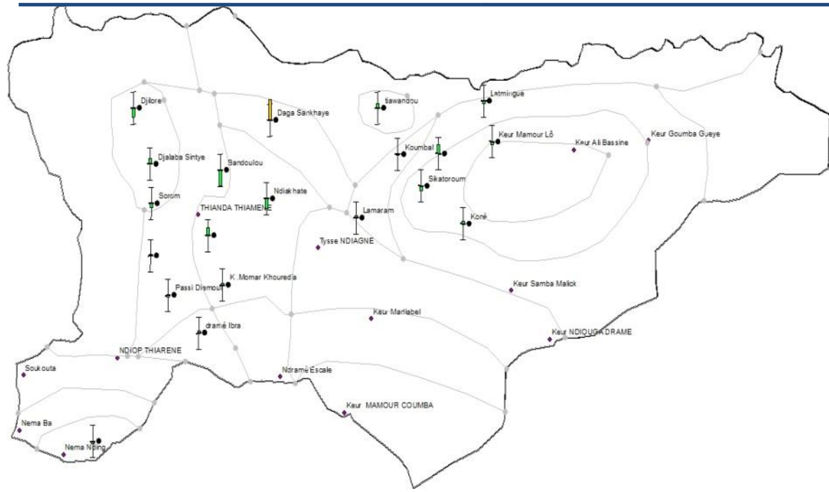
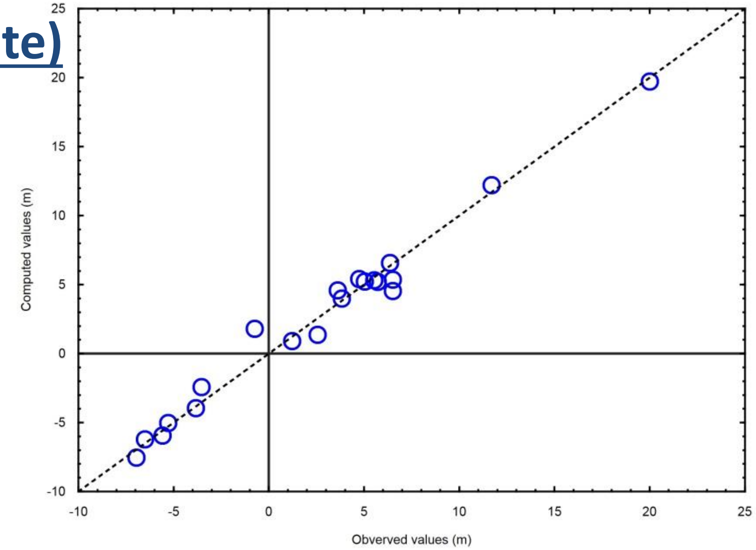
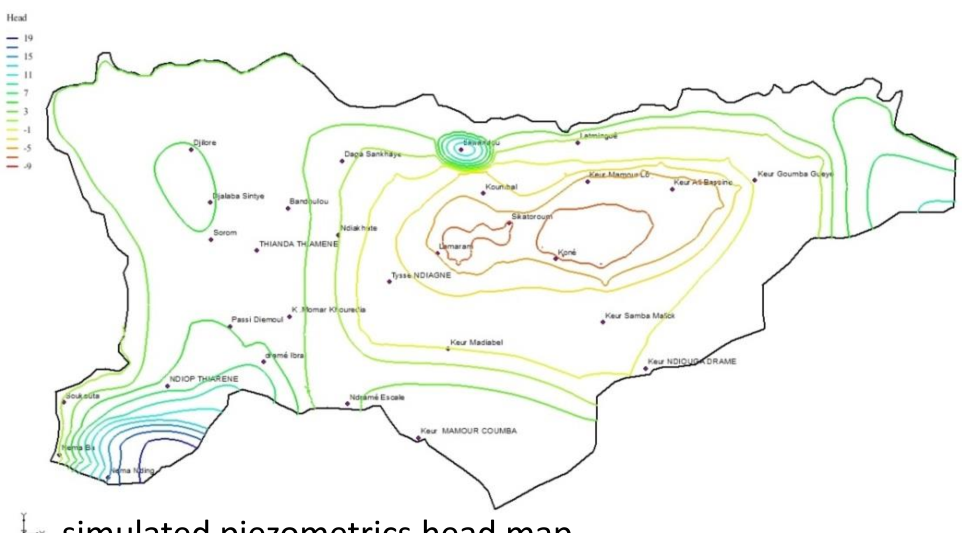
Calibrations results : Initial condition (steady-state)



Distribution of calibration control points in November 1973 (steady-state)
(error ranging from -2.5 m à +1.9 m)



Graphical analysis of the model calibration: computed values *vs* observed values in steady-state



simulated piezometrics head map

5.10^{-7} < K (m/s)< 6.10^{-4}

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Mean error between computed and observed head for the observation wells

Parameters	Values (m)
Erreur moyenne (EM)	-0.02
Erreur moyenne absolue (EMA)	0.6
Erreur quadratique moyenne (RMSE)	0.9

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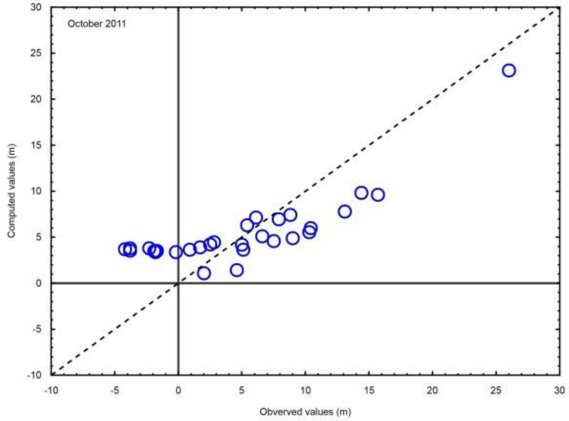
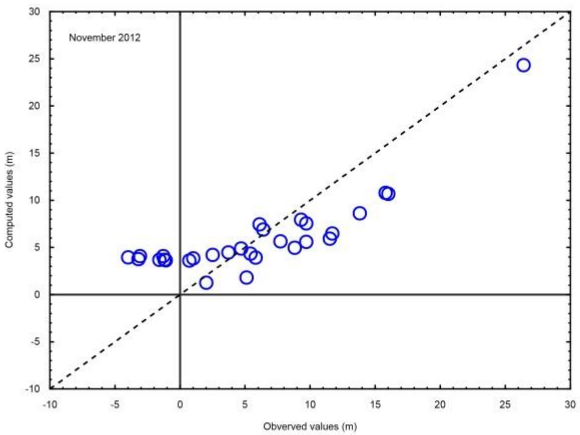
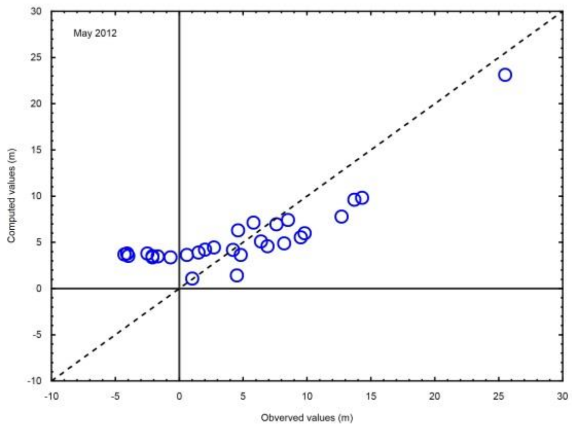
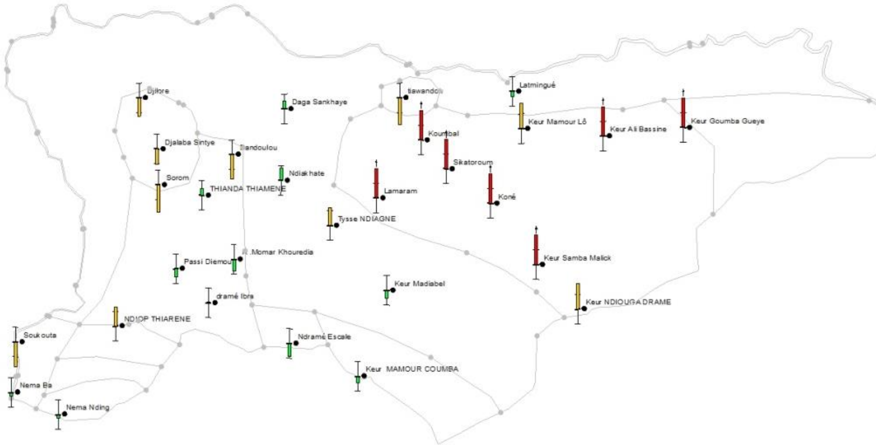
Calibrations results : Transient condition







Graphical analysis of the model calibration: computed values *vs* observed values October 2011, May 2012 and November 2012



Distribution of calibration control points in November 2012 (error ranging from -3.8 m to +8.6 m)

Mean error between computed and observed head for the observation wells

Parameters	Values (m)
Mean residual	-1.7
Mean absolute residual	2.3
RMSE	4.1

Despite the low number of measured data, the model can be considered satisfactory

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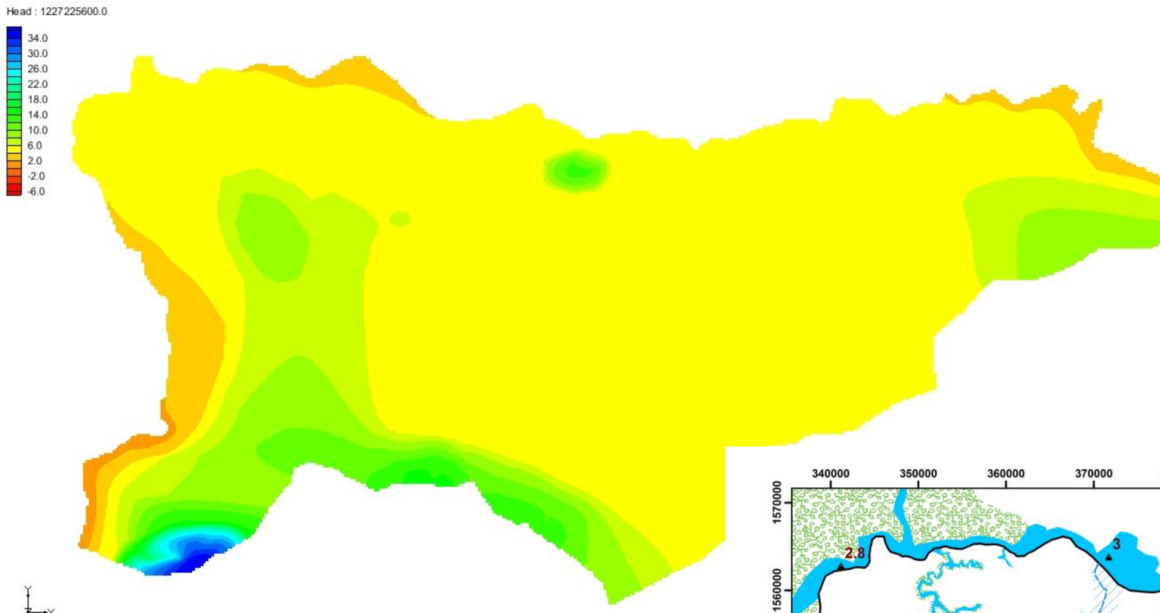
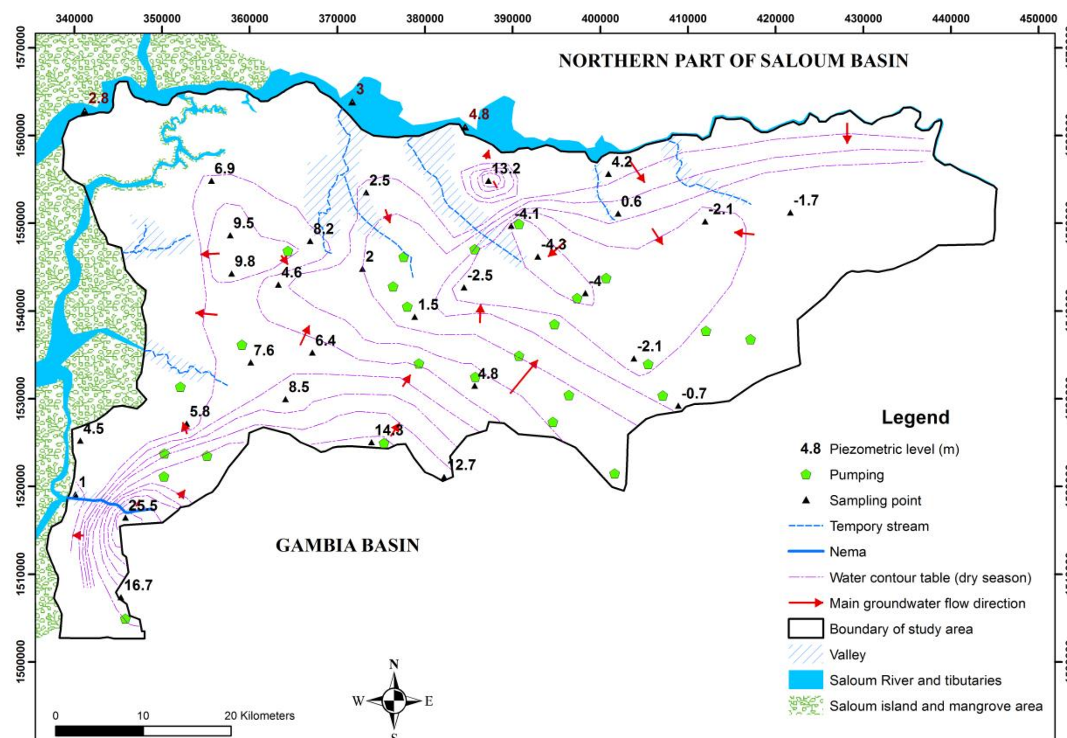
Calibrations results : Transient condition



Simulated vs observed piezometrics head in May 2012



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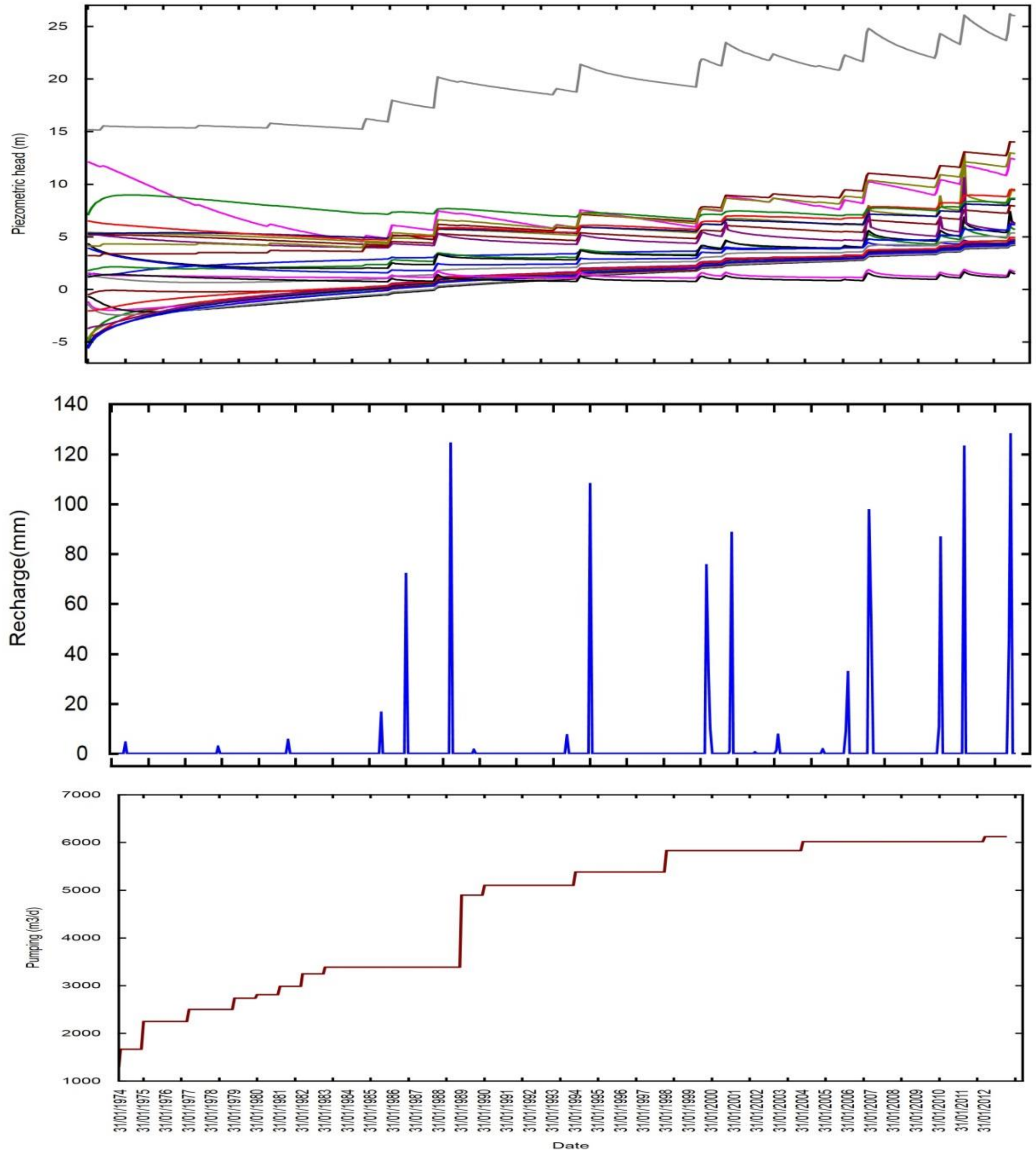
Transient condition results (1974-2012)



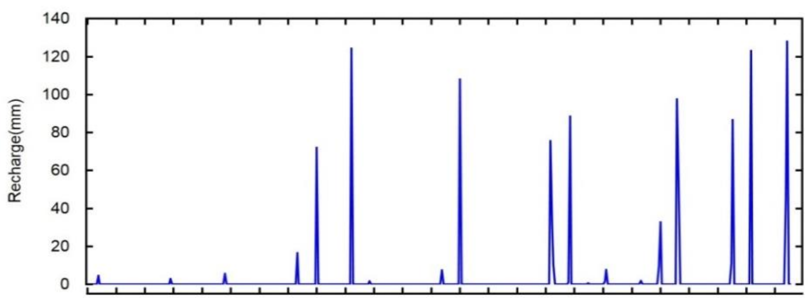
a global increased in groundwater levels related to recharge evolution

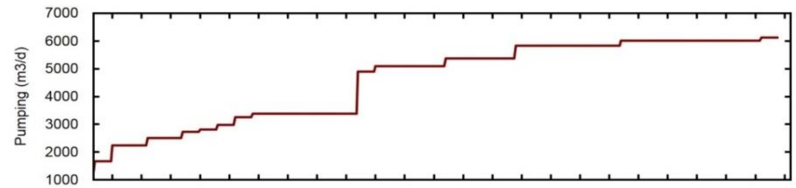
Simulated piezometric head, recharge and pumping rate evolution during the period 1974 to 2012

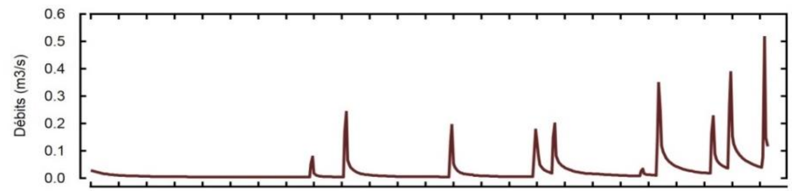
❑ Calibrations results : Transient condition

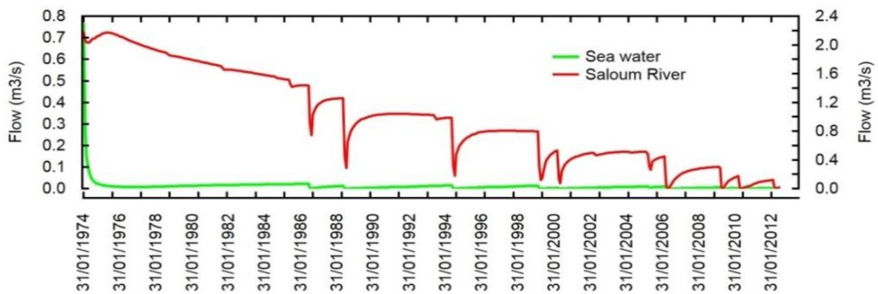
Simulated water balacance terms for the period 1974 - 2012

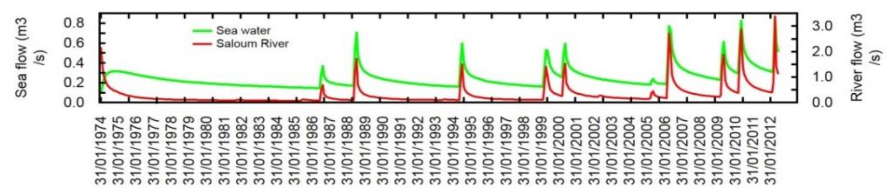
Periode	Recharge	Seawater intrusion	River intrusion	Pumping	Drains	Sea discharge	River discharge
1974-2012	2.05	0.01	0.99	-0.05	-0.03	-0.25	-0.30

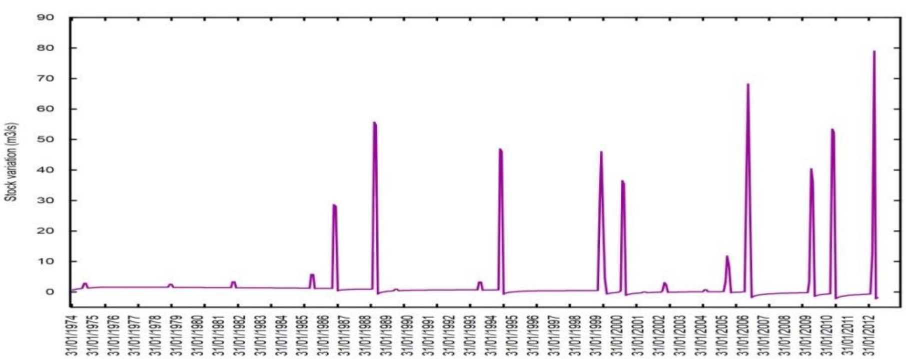






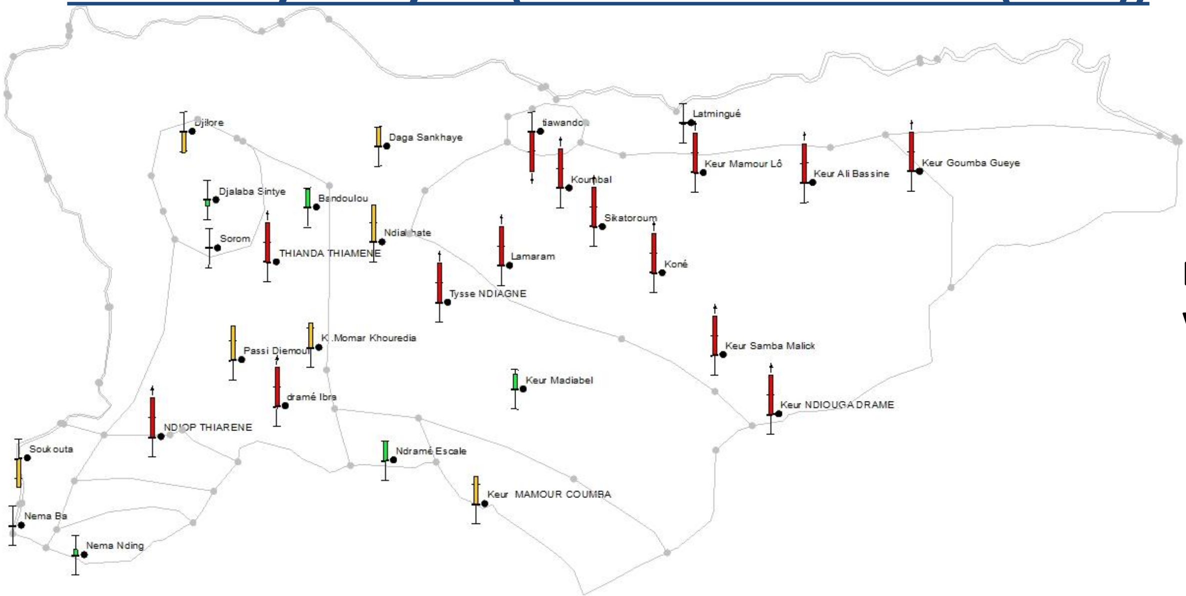




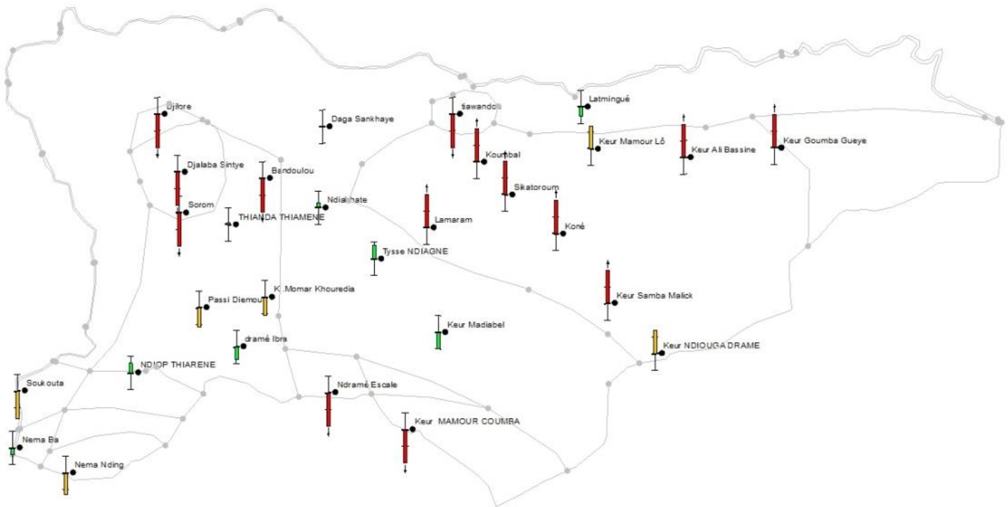


Dynamic of the Simulated water balacance terms for the period 1974 - 2012

❑ Sensitivity analysis (Soils water retention (SWR))



Decrease of 25% of soils water retention value



Increase of 25% of soils water retention value

	SWR (mm)	Recharge(mm)	Error (m)
	103-177	0 - 127	-7.3 et 10.4
-25%	78-132	0 - 177	-0.4 et 10.4
25%	129-221	0 - 115	-5.5 et 8

In sensitivity analysis, the effect of the recharge was investigated using the soils water retention value and show the model is highly sensitive to this parameter;

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CONCLUSION

- ➢ changes of groundwater levels have been observed in the CT aquifer over several years in response to variations in the precipitation regime variation and other factors;

- ➢ water input comes from mainly from recharge and to lesser from Salt water (sea and Saloum River) . This later decrease when the recharge increase

- ➢Water output comes from streams, sea and Saloum River. Pumping well rate constitute a low part of water output.

- ➢These changes and particulary the salt intrusion are closely related with to rainfall variation in this region and are harmful for the social and economical development, due to the importance of the groundwater for the sustainability of human settlements in Saloum area .

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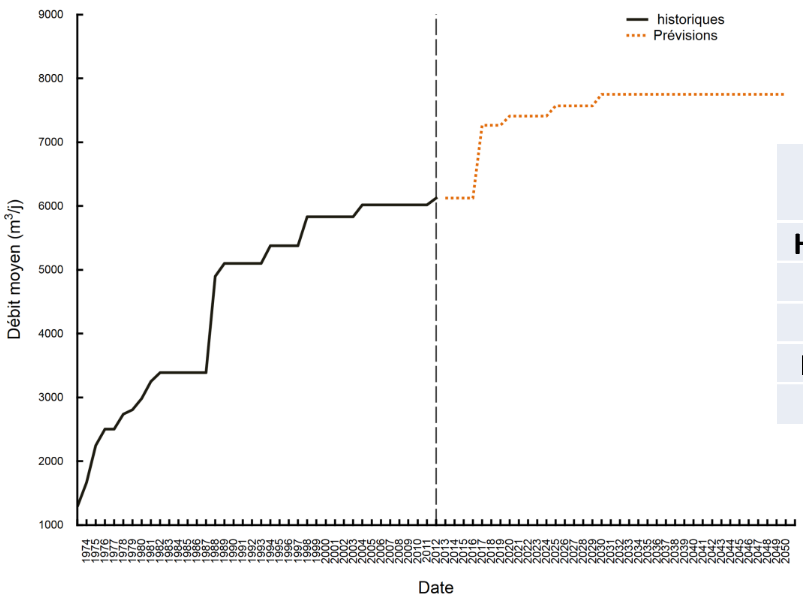
❑ Perspectives:

- ❖ Use geophysical data **to improve** the calibration;

- ❖ Additional changes in recharge or in the flow regime will occur in the near future in response to **climate change** and more **groundwater pumping** will be increasing (25 %) in order to **improve water supply** in other **disadvantaged areas** in Senegal ;

- ❖ It is thus important to identify the evolution of the groundwater levels and fluxes water with the Saloum River that is caused by these new changes to avoid or mitigate the future degradation of groundwater quality before it becomes a major obstacle to the future economic development of this coastal area.

Despite the low number of measured data, the model can be considered as the current best assessment tool for future predictions in the Saloum region



Climatic scenarii from Coordinated Regional climate Downscaling Experiment (CORDEX, Giorgi *et al.*, 2009)

	GCM	periode	P (mm/an)	ΔP(%)	Types of scénarii
Historical		1974-2012	592		
Canada	CanESM2	2013-2050	520	12	Optimiste
UK	HadGEM2	2013-2050	503	17	
Norvege	NordESMI	2013-2050	380	42	Pessimiste
Moyen	Moyen	2013-2050	467	32	Mean

THANK YOU