# SATELLITE BASED RAINFALL DATA AND FLOODING OVER THE OKAVANGO RIVER BASIN IN SOUTHERN AFRICA.

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## Abstract

As part of the EU-funded project "*Water and Ecosystem Resources in Regional Development – Balancing Societal Needs and Wants and Natural Resources Systems Sustainability in International River Basin Systems*" (WERRD) research has been carried out aiming to improve and develop scientific methods that will facilitate the understanding of fluctuations of hydrological and ecosystem variables and likely human-induced trends concerning key characteristics of the Okavango River Basin in Southern Africa. The Okavango river basin spans the three riparian states of Angola, Namibia and Botswana ending in a large (22,000 $km^2$) alluvial fan subject to annual flooding. The extent of flooding varies seasonally from low in December (3000-5000 $km^2$, depending on year) to high in August (6000-12000 $km^2$). Water for the delta is primarily delivered as rainfall, upstream over Angola. Due to the 20-year civil war in Angola there is little recent raingauge data with which to model the hydrology of the river. To overcome this data gap a 10-year database of daily satellite derived rainfall data at 10km spatial resolution has been produced using data from METEOSAT, Special Sensor

Microwave/Imager and the Tropical Rainfall Measuring Mission. Details of this dataset are presented in this paper within the context of the modelling of the Okavango river and delta. Preliminary analysis of the data reveals a considerable wetlands effect with recycling of flood waters as rainfall over the delta.

## The Okavango River Basin

The Okavango River Basin, with a total basin area of 530,000 km$^2$, has about 95% of the water flow in the river contributed by 135,000 km$^2$ of the catchment, situated within Angola. Increased water take-off is anticipated in the Angolan and Namibian head streams in response to water shortages and increased agricultural demand. With regard to Angola, it is expected that more than 1 million people in refugee camps gradually will return to areas close to the river. There are also old plans for hydroelectric power generation in Cuito and Cubango that may be taken up again. Also in the Namibian part of the river basin, increased irrigation demand may be expected, in addition to a planned pipeline for water withdrawal.

The Okavango Delta is a large alluvial fan, tectonically forced, subject to annual flooding. It is composed of a mosaic of floodplains and islands. Due to the large distance from the source area of the feeding Okavango River, the annual flood wave arrives at the Delta apex two months later then the rainy season in Angola. The flood wave undergoes further attenuation during its spreading in the Delta proper, so that the most downstream areas are flooded only in August – i.e. approx. 6 months after the rainfall that generated the flow. The extent of flooding varies seasonally from low in December (3000-5000 km$^2$, depending on year) to high in August (6000-12000 km$^2$). Surface inflow amounts to 10000 Mm$^3$ year$^{-1}$ while rainfall supplies approx. 5000 Mm$^3$ year$^{-1}$. Out of this, approx. 200 Mm$^3$ year$^{-1}$ leaves the Delta in the form of surface runoff, and it is estimated that another 200 Mm$^3$ year$^{-1}$ flows out through the groundwater pathways. This indicates that approx. 97% of the total input is ultimately evaporated. The low topographic gradient of the Delta (1:3470) causes low flow velocities; flow takes place partly through channels, but also through sometimes densely vegetated floodplains. The propagation of the flood front is associated with a rising groundwater table, both within floodplains as well as under the islands. Continuous flow of groundwater between floodplains and islands is responsible for removal of solutes from the system and their immobilisation in the islands groundwater and soils.

Of particular significance in the Okavango ecological systems are impacts which may occur as a result of external factors in the Okavango River Basin upstream of Botswana with possibly detrimental hydrological and ecological effects. Responses to drying of former floodplains may include localised species extinctions leading to changes in community functions (cf. Thibodeau and Nickerson 1984, Fonseca and Ganade 2001) and bush encroachment (e.g. Ringrose *et al*. 1997).

## Aims of the hydrological studies within WERRD

One of aims of the WERRD project is to assess river flow in the river basin and its sub-catchments using a combination of remote sensing and historical hydrological and climatological.

## Rainfall over the basin

The precipitation data set used to create the interpolated areal coverage consists of daily and monthly average values from 262 stations. The number of stations was greatest between 1960 and 1972 and after the onset of the Angola civil war the number of recording stations was drastically reduced. The data collected was taken from the Nicholson African rainfall database available from the National Center for Atmospheric Research (NCAR) Data Support Section (monthly rainfall totals 1901-1975) found on the Miombo CD (a production of the Land Cover Change (www.icc.es), International Project Office and the Miombo Network (www.miombo.gecp.virginia.edu), Servicio Meteorologico de Angola at the National Meteorological Library, UK and the Botswana Meteorological Office.

Historical satellite based rainfall products for the region has been constructed, using data from Tropical Rainfall Measuring Mission (TRMM), Special Sensor Microwave Imager (SSM/I) and METEOSAT. These sensors have different spectral properties and varying spatial and temporal resolutions, coverages and overpass times. As a tropical orbiter TRMM samples the diurnal cycle of rainfall, whereas SSM/I is restricted to morning and afternoon overpasses due to the satellites' polar orbiting sun-synchronous orbit. However SSM/I does have the advantage of data stretching back to 1988 compared to 1997 with TRMM. METEOSAT has the best spatial and temporal resolution, longest time coverage but unlike its microwave counterparts, measures electromagnetic radiation at wavelengths that are not directly related to rainfall and thus relies on indirect and 'physics poor' transfer functions to estimate rainfall. Todd et al (2002) has been involved in the development of synergistic methods to provide satellite based rainfall products using histogram matching and neural networks (Bellerby et al 2000). While these 'proof of concept' studies have provided potential methodologies for combining satellite datasets they have made no attempt to quantify the uncertainty in these predictions other than elementary 'validation' statistics. Such estimates are important for the quantification of uncertainty in hydrological output to be used in policy framing. In the work carried out so far TMI data has been sub-sampled at SSM/I times and compared to PR and all the TMI data to calculate a diurnal correction factor for SSM/I data. The variation in this function has been calculated temporally and spatially. The diurnally corrected SSM/I data (Figure 1) has then been combined with METEOSAT data to produce daily 5 km rainfall data. In Figure 2 the average daily rainfall from this procedure is shown for the Okavango region for the months of March April and May. This high resolution data shows a possible (and until now unrecognised) local rainfall effect over the delta which is being currently being explored further. The high temporal resolution data also allows the calculation of the probability of rain following a day with no rain etc. These probabilities are useful in simulating the evaporation demand in the basin. The results from the study show that there is a strong diurnal component to the rainfall, where the form of the diurnal cycle varies spatially over southern Africa. SSM/I underestimates rainfall in the morning and overestimates in the evening. However, for the Okavango region, correcting factors can be found for SSM/I and errors can be estimated.

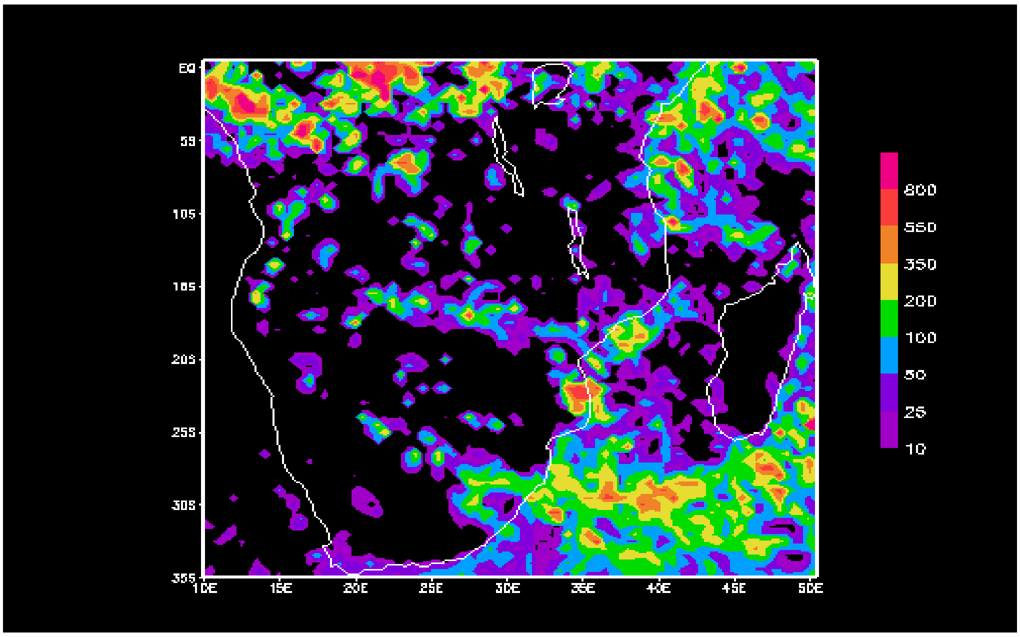


Figure 1. Rainfall for March 2001(in mm month$^{-1}$) – diurnally corrected SSM/I.

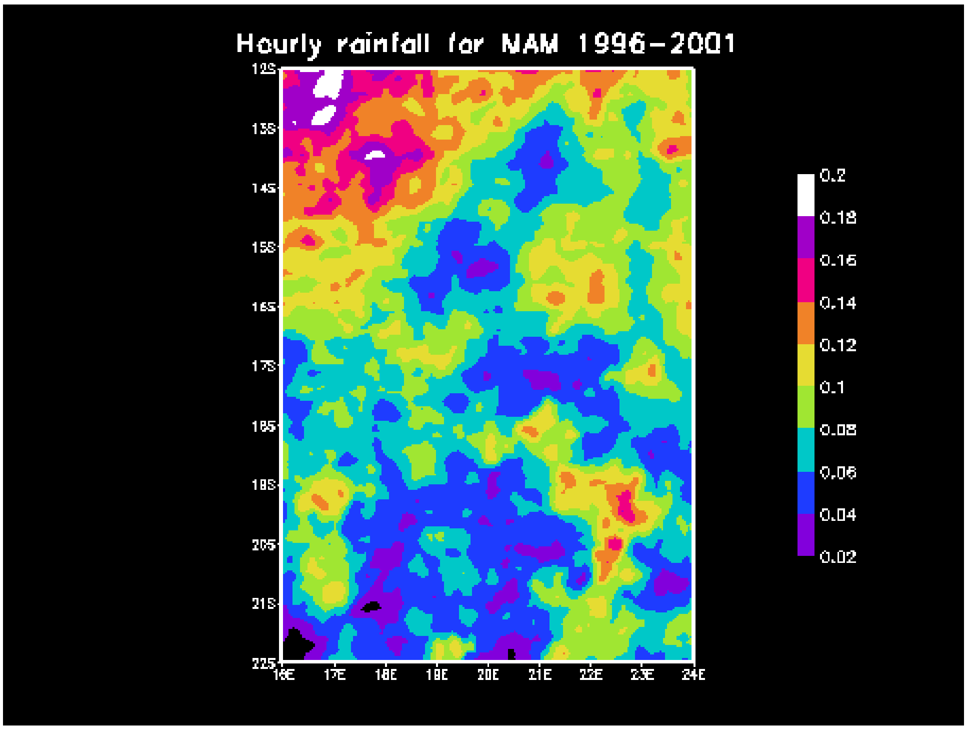


Figure 2. Average daily rainfall from 1996-2001 for the months of March, April and May at 0.1 degree spatial resolution. The units are in mm/h

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