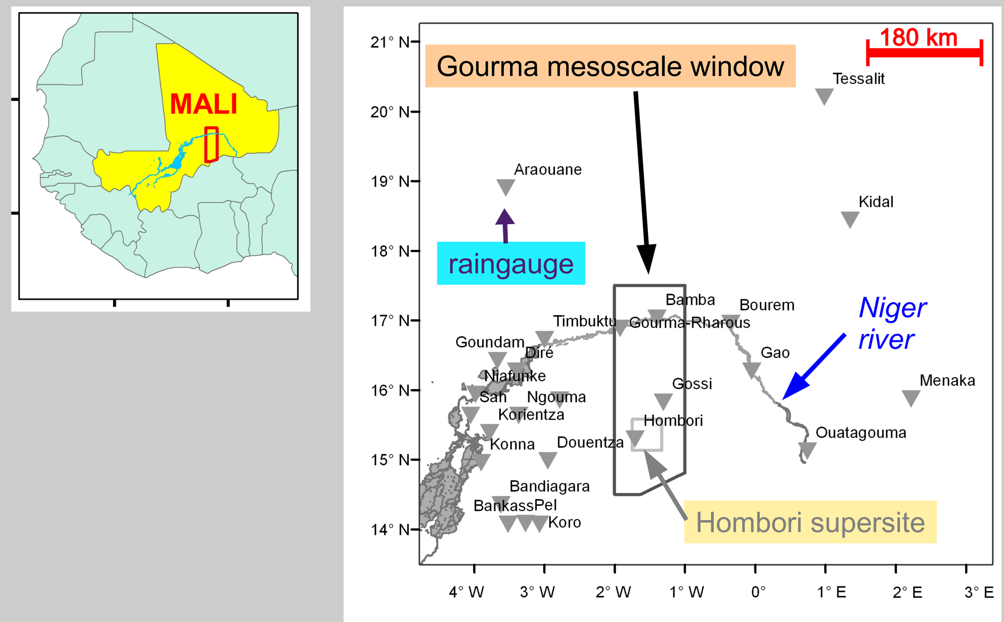
A MULTI-SCALE ANALYSIS OF IN-SITU PRECIPITATION DATA ACROSS THE SAHELIAN GOURMA

F. Guichard[1*], F. Frappart[2], P. Hiernaux[2], L. Kergoat[2], E. Mougin[2], M. Arjounin[3], M. Koité[4], T. Lebel[3], O. Bock[5,6], and R. Meynadier[5]

(*) francoise.guichard@meteo.fr   1: CNRM, CNRS and Météo-France, 2: LMTG (CNRS, IRD, UPS), 3: LTHE (CNRS, UJF, IRD, INPG) (4) DNM Mali, 5: LATMOS (CNRS, Univ. Paris 6), 6: LAREG, IGN



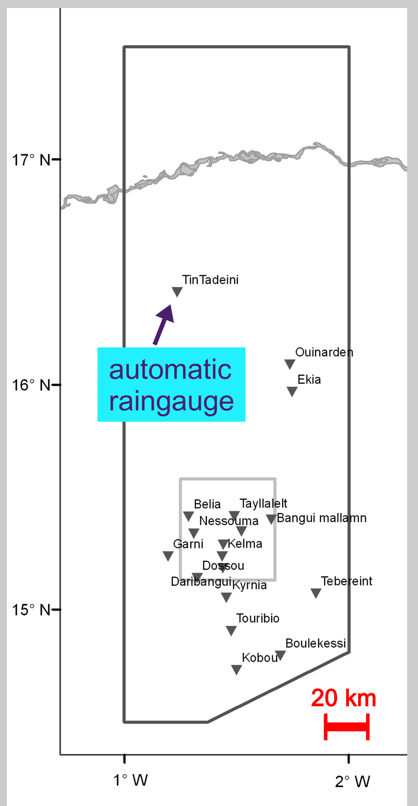
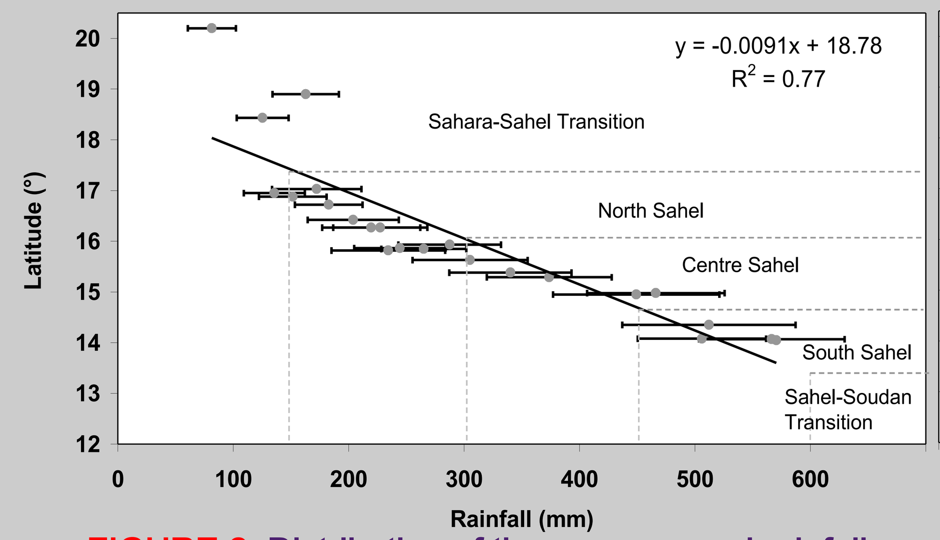


FIGURE 1 Location of the Gourma region in West Africa, map of historical rain gauges (25 stations) within and outside the Gourma region (middle) and (c) zoom on the automatic rain gauges network (20 stations).

A sharp meridional gradient of rainfall



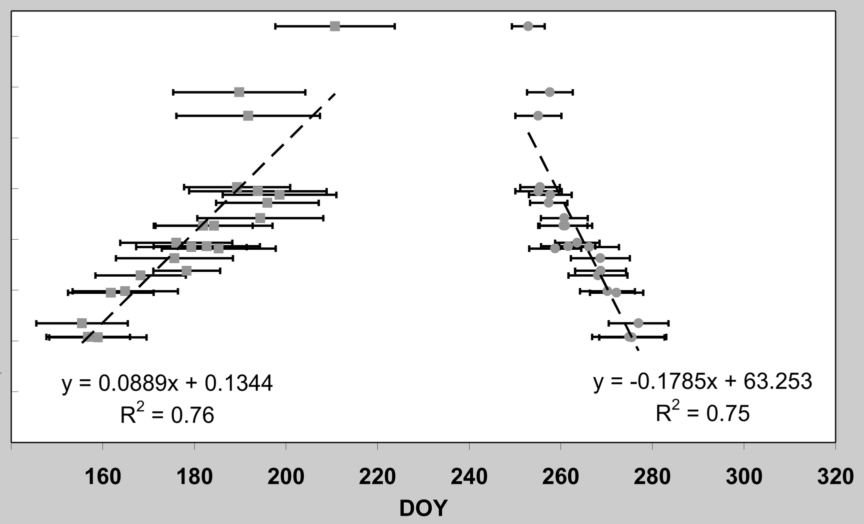


FIGURE 2 Distribution of the mean annual rainfall as a function of the latitude.

FIGURE 3 Starting and ending dates of the rainy season as a function of the latitude.

Variability at decadal scales *rainfall amount & intensity*

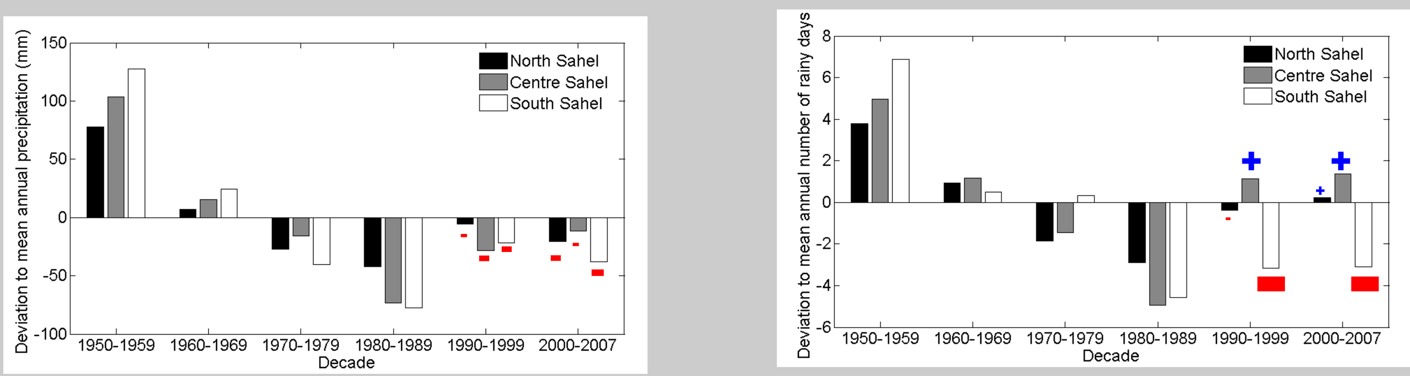


FIGURE 4 left : deviations from the mean annual precipitation over each climatic zone (northern 183 mm, central 292 mm and southern Sahel, 504 mm) and (b) deviations from the mean annual number of rainy days (northern 21 rainy days, Central 29 rainy days and southern Sahel 37 rainy days).

CONTEXT & DATASETS

Droughts and floods are recurrent features of the Sahelian climate, which is also characterized by a very large variability of rainfall, in both space and time. The present study focuses on the Malian Gourma (2°W-1°E, 14.5°N-17.5°N), located in the Central Sahel, where the very large majority of rainfall events occur between June and September, during the West African monsoon (Mougin *et al*. 2009).

Rainfall is analysed with two complementary in-situ datasets: (i) daily rainfall series from 25 stations covering the period 1900–2007, and provided by the Direction Nationale de la Météorologie of Mali, and (ii) high-frequency rainfall data provided by a network of about 20 tipping bucket rain gauges, starting in 2005 – these rain gauges have been installed for the African Monsoon Multidisciplinary Analysis (AMMA) (see map FIG 1). More details on this study in Frappart et al. (2009)

RESULTS

The Gourma displays a particularly marked meridional gradient, with annual rainfall decreasing from about 500 mm at 14°N to 150 mm at 17.5°N where the rainy season is also shorter (FIGS 2 & 3). In line with previous studies focused on the Sahel, the area also displays a strong decadal variability, with the same succession of wet (1950–1969) and dry decades (1970–2007) (FIG 4).

The length of the rainy season has varied since the 1950s with two episodes of shorter rainy seasons: during the drought of the 1980s and also since 2000. However, this second episode is characterized by an increase in the daily rainfall, which suggests an intensification of rainfall events in the more recent years (FIG 4).

Rainfall is mostly provided by MCSs (see FIG 5) and interannual variability of rainfall is strongly linked to the number of the rainy days in southern Gourma, but also to daily rainfall in northern and central Gourma (FIG 6). This latter result contrasts with some studies focused on more southern areas.

High-frequency data show that most rainfall is produced by intense convective events whose characteristics are quantified at fine scale. Rainfall amount displays too peaks in the diurnal cycle, one in the evening and one in the early morning, but with distinct patterns in the early (June) and core (August) monsoon periods (FIG 7). Conversely, rainfall amounts are less around noon, and this mid-day damping is more pronounced in the northern Gourma.

Surface meteorological data and ECMWF analyses highlight links between this feature and the diurnal cycle of equivalent potential energy and CAPE (not shown, see Guichard *et al.* 2009). Late afternoon and evening maxima are consistent with the afternoon convective triggering, while the morning maximum involves the life cycle of mesoscale convective systems (MCSs). This second maximum is consistently less pronounced in June prior to the Sahelian monsoon onset and the more frequent development of MCSs.

These results provide a necessary ground truth for satellite and radar rainfall products, as well as model evaluation over a region where rainfall has remained largely undocumented. This is illustrated in FIG 9 with results from commonly used satellite estimates (GPCP, CPC-RFE2, TRMM) and forecasts from ECMWF, NCEP and ARPEGE analyses and/or reanalyses (see Meynadier *et al.* 2010 a,b). The spread is still very important at large scale & meridional gradients differ markedly.

Rainfall, convection & MCSs

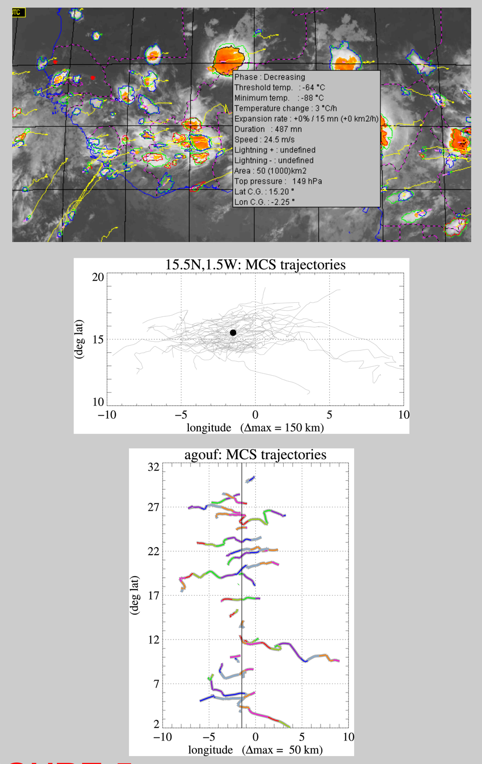


FIGURE 5 rainfall and MCS, (top) an illustration of the tracking algorithm ISIS (Morel and Senesi QJ 2002), (bottom) trajectories of detected MCS for JJAS 2006 within a 150 km radius (r) centred on the Gourma window and a zoom on MCS around Agoufou

Rainfall, # of events & rain per event

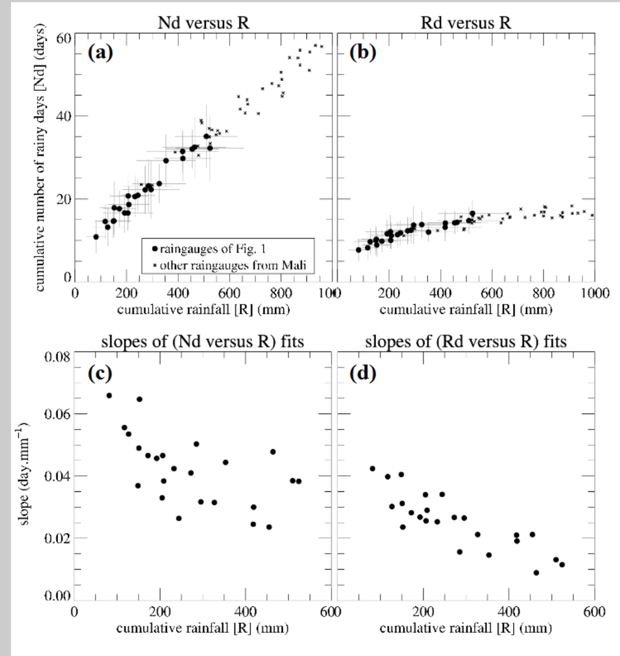


FIGURE 6 (a) Average number of rainy days (Nd) for each station versus average JJAS rainfall (R) – full circles: Gourma region, dots: southern Malian stations ; (b) mean rainfall per rainy day (Rd) for each station versus average JJAS rainfall (R) ; (c) slopes of the linear regression between R and Nd for each Gourma stations ; (d) as (c) except for slopes of the regression between R and Rd.

Diurnal cycle

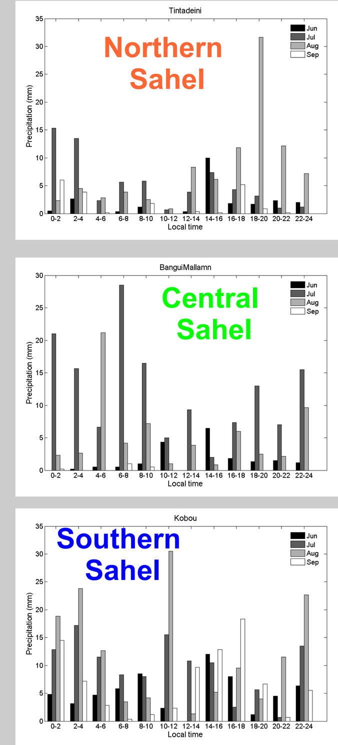


FIGURE 7 Rainfall diurnal cycle of rainfall monthly mean from June to September, with 2005 to 2007 data in Tin Tadeini (top), Bangui-Mallam (middle) and Kobou (bottom)

Evaluation of satellite products and models

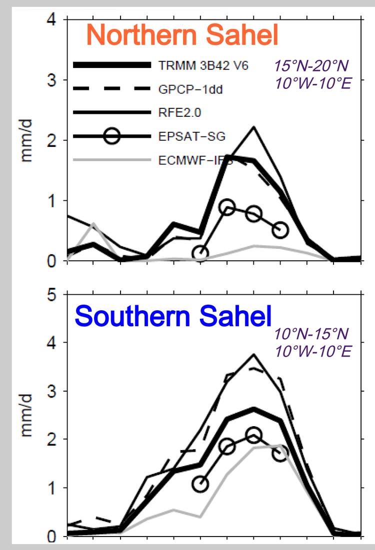


FIGURE 8 monthly mean time series of rainfall from satellite products

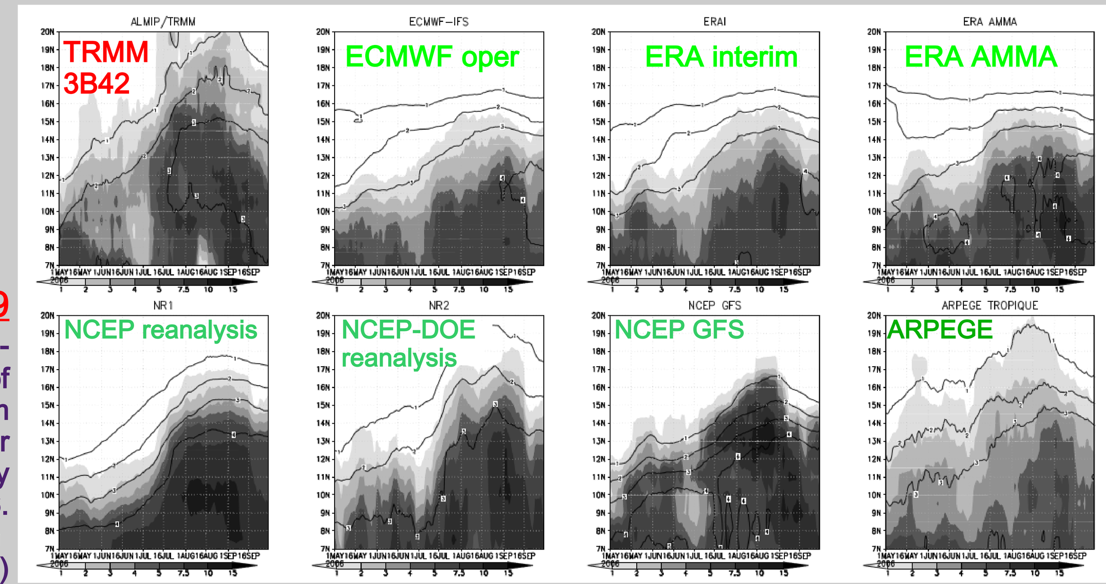


FIGURE 9 comparison of time-latitude diagrams of rainfall (shaded) from NWP averaged over 10◦W-10◦E, for May to September 2006. 15-day running mean (mm.day−1)

QUESTIONS & PERSPECTIVES

a valuable dataset for further validation of rainfall products & models

intensification, weakening of rainfall? Why? changes in ITD?

analyse of a larger dataset and use of reanalyses

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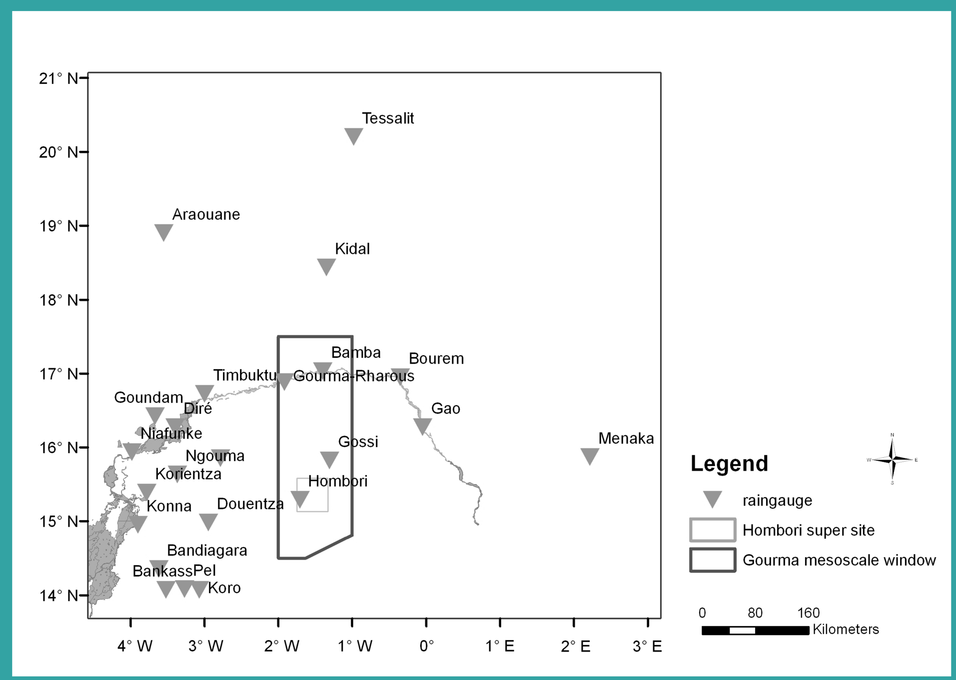
21° N
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17° N
16° N
15° N
14° N
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Timbuktu
Gourma-Rharous
Goundam
Diré
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Niafunke
Menaka
Gossi
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Korientza
Hombori
Konna
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Bandiagara
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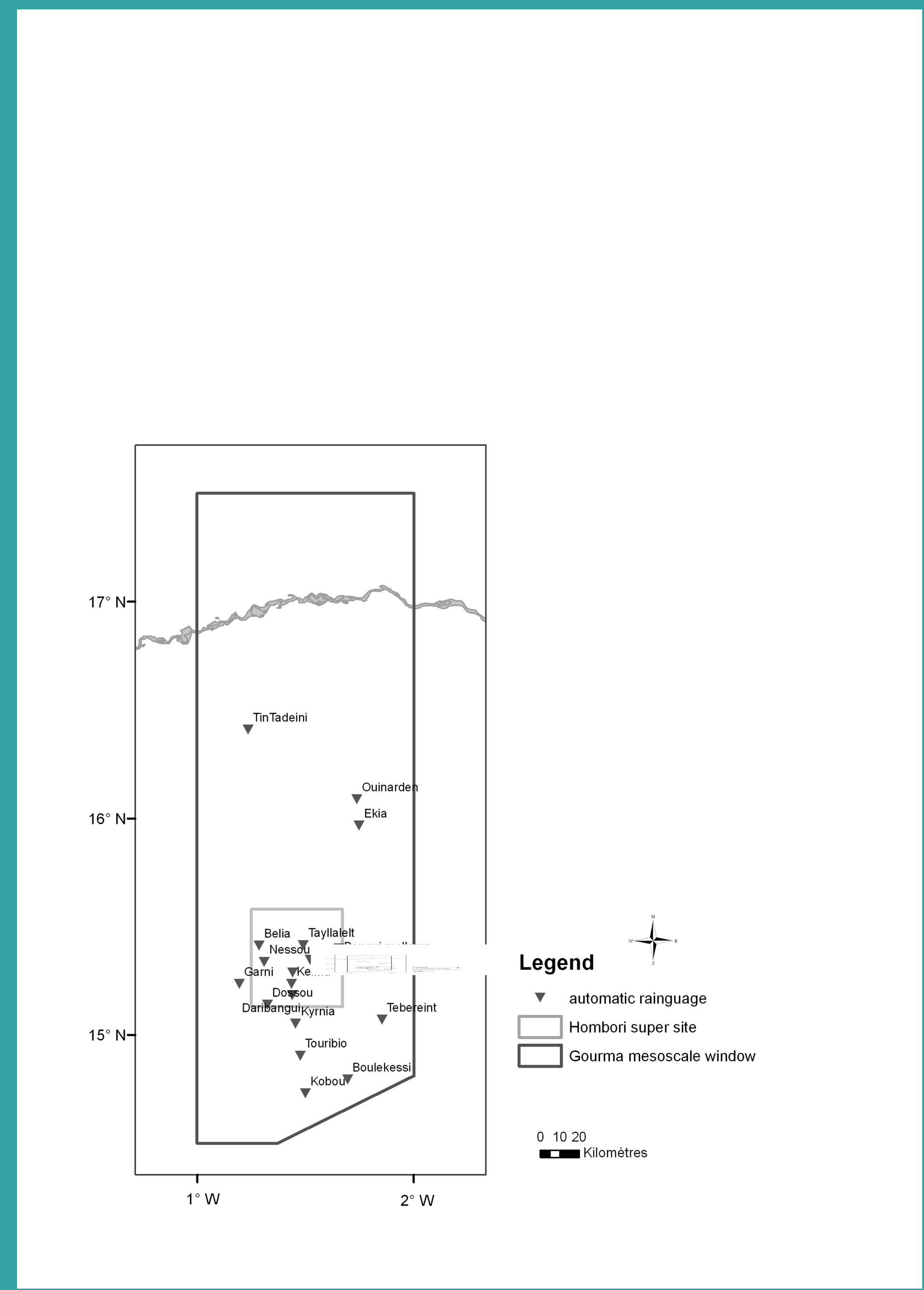
17° N
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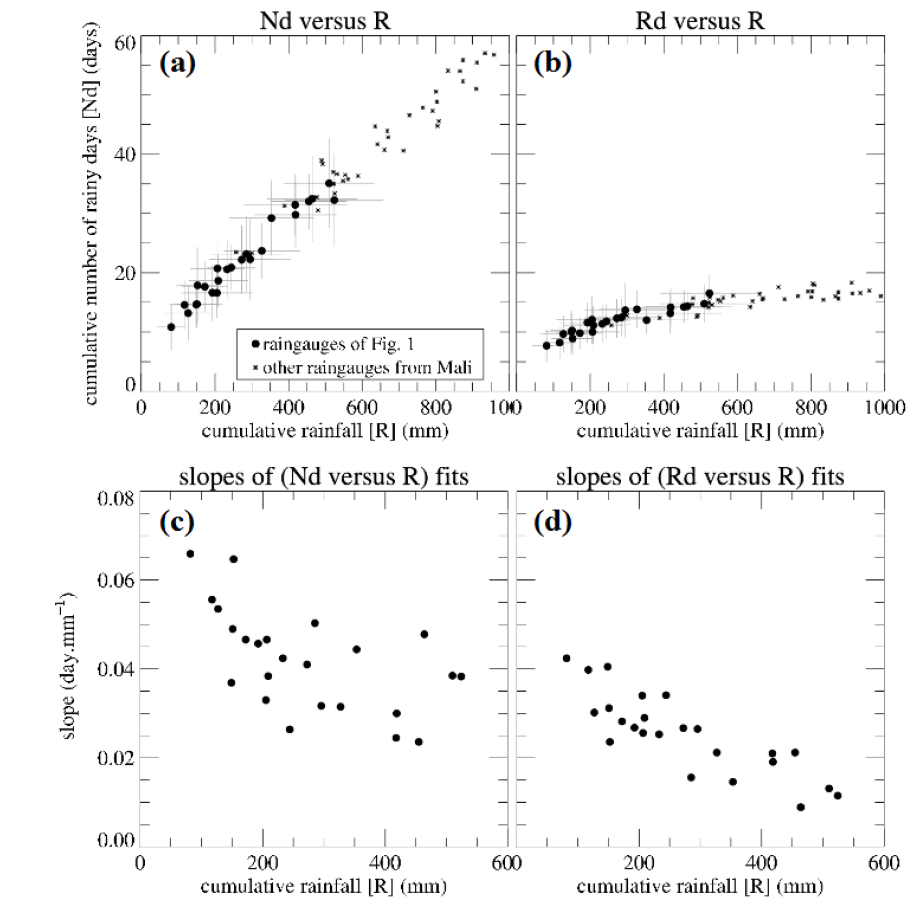
Nd versus R
Rd versus R
(a)
(b)
cumulative number of rainy days [Nd] (days)
raingauges of Fig. 1
other raingauges from Mali
cumulative rainfall [R] (mm)
cumulative rainfall [R] (mm)
slopes of (Nd versus R) fits
slopes of (Rd versus R) fits
(c)
(d)
slope (day.mm^{-1})
cumulative rainfall [R] (mm)
cumulative rainfall [R] (mm)