Chapter 1

Overall Observing Strategy in AMMA

1 A brief reminder of the AMMA Scientific objectives

The three overarching goals of AMMA, as given in the AMMA International Science Plan (ISP) are:

(1) To improve our understanding of the WAM and its influence on the physical, chemical and biological environment regionally and globally;

(2) To provide the underpinning science that relates climate variability to issues of health, water resources, food security and demography for West African nations and defining relevant monitoring and prediction strategies;

(3) To ensure that the multidisciplinary research is effectively integrated with prediction and decision making activity.

A detailed description of all the interlaced scientific questions deriving from the above overall objectives is given in the ISP. The ambition of the programme is both to improve our understanding of the numerous processes that are the skeleton of the WAM and to gain a new knowledge on how these processes interact to form a climatic system, characterised by a great interannual and decadal variability. The consequences of this variability for the population are huge. Unreliable rainfall, poor predicting capacity, rapid modification of the environment combine to produce harsh agricultural conditions and to threaten the success of development policies.

The AMMA observing program reflects the complexity of its scientific agenda. While individual processes are often spanning a limited range of scales, documenting them all, as well as their interactions, requires a specific observing program covering a broad range of relevant scales, from regional to local. Factors originating outside of the study area have been demonstrated to interfer with the WAM, which draws attention towards the global scale. Impact of the WAM variability on population is felt at the scale of the field plot, which means studying how the regional scale variability is transferred to the local scale.

2 Space and time scales of the AMMA observing program

In order to elaborate a coherent observing strategy and to take into account the multi-scale nature of the various components of the West African monsoon, the observing strategy of AMMA is built around a combination of different study areas and observing periods. These are designed to sample the main space and time scales of interest to AMMA.

2.1 Space scales and study areas

Four main interacting spatial scales are identified, as illustrated in Figure 1.1 above :

(i) ***Global scale***. This is the scale at which the WAM interacts with the rest of the globe; emphasis is given to improving our understanding of the role of global SST patterns on WAM variability; seasonal-to-decadal variability are the main time scales of interest. On this scale we are also concerned with the impacts of chemical and aerosol emissions from the monsoon system on the entire global climate.

(ii) Regional scale. This is the scale at which emphasis is given to improving our understanding of the interactions between the atmosphere, land and tropical Atlantic ocean (especially the Gulf of Guinea). It is important to study the role of surface feedbacks on variability of the WAM at this scale, including the key roles of vegetation and soil moisture over the continent and SSTs in the Gulf of Guinea. African Easterly Waves (AEWs) and other synoptic systems are also studied at this scale. This scale corresponds to a window larger than the one shown in Figure 1.1; it includes a larger portion of the Ocean to the West and to the South, extends North to the Heat Low (sounding stations in Tessalit and Tamanrasset) and East to Soudan (sounding station in Khartoum).

(iii) Mesoscale. This is the scale of the typical rain-producing weather systems in the WAM. It is central for studying the variability of rainfields at the seasonal scale and the coupling between hydrology and the atmosphere at the catchment scale. It is important to study the interactions of the mesoscale weather systems with synoptic scales (e.g. AEWs). In Figure 1.1, this scale is illustrated by the Ouémé catchment (14600 km²).

(iv) Local scale or sub-meso scale. From an atmospheric point of view, this is the convective rain scale, of a few kilometres; it is central to the hydrology of the Sahel and of small watersheds to the south; it is the main scale of interest for agriculture. In Figure 1.1, this scale is illustrated by the Donga catchment (576 km²)

AMMA emphasizes the importance of improved understanding of how these scales interact and combine to characterize the WAM and its variability, including how these interactions impact sources and transport of water vapour, aerosol and key chemical species (e.g. key greenhouse gases, ozone and aerosol precursors) in the West African region and globally.

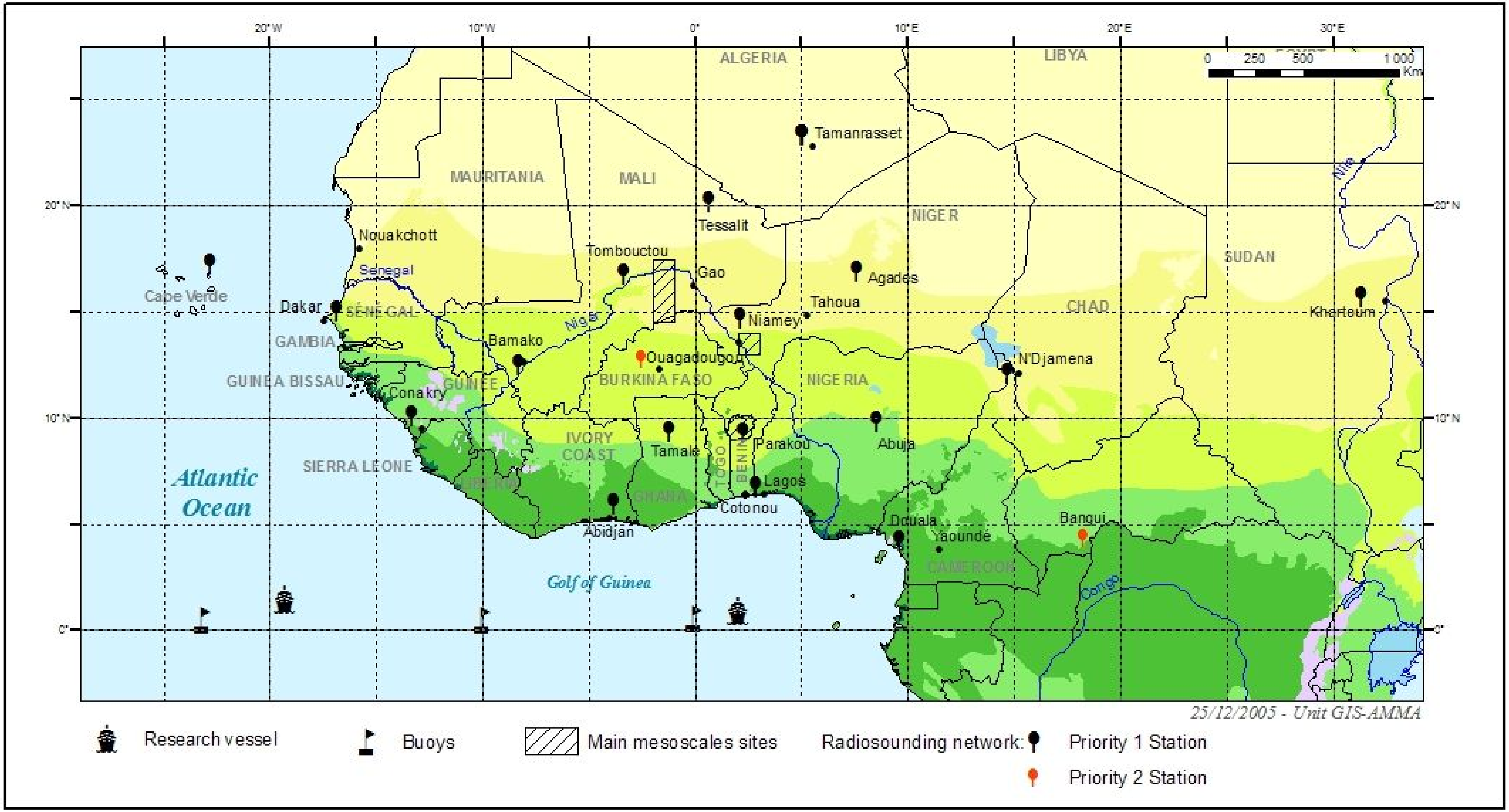

Fig 1.1. The regional scale AMMA study area. The radiosounding stations on the continent and the PIRATA buoys are the primary source of in situ information at that scale, in addition to the observations of the meteorological and hydrological operational networks.

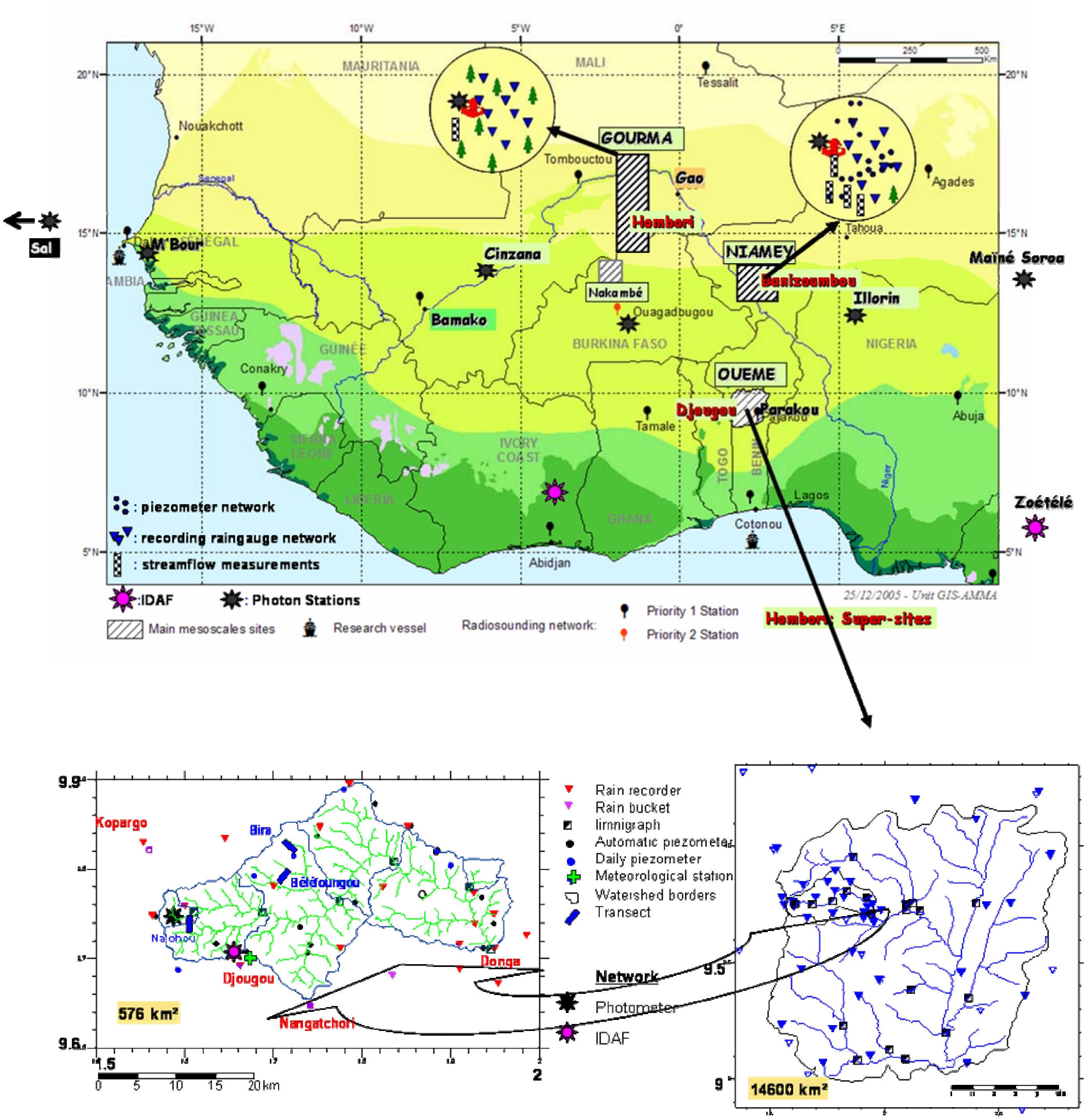

Fig 1.2. The long term AMMA observations on the continent. On the continent, the regional scale is monitored both through operational networks and specific networks (PHOTON, IDAF for aerosols and wet/dry deposits). The three mesoscale areas (Gourma, Niamey, Ouémé) include so-called super-sites and intensive local sites (as shown by the zoom on the Ouémé catchment). Another mesoscale site is the Nakambé catchment in Burkina-Faso.

2.2 Time scales and periods of study

Three periods of study are considered in order to sample the interannual variability and the intraseasonal variability as well as to be able to properly document the mean seasonal cycle, and possible decadal scale trends. These three periods are the Long term Observing Period (LOP: 2001-2010), the Enhanced Observing Period (EOP: 2005-2007) and the Special Observing Period (SOP: 2006).

2.2.1 LOP

Given the great variability of climatic conditions from year to year, observations are needed over several annual cycles in order to gain a proper vision of the diversity of the seasonal cycles, around a mean state which is only a statistical concept, but is never observed as such. The operational networks are precisely intended at this type of monitoring. However, operational networks are not dense enough to sample properly the spatial scales of interest when studying the links between the climate, the water cycle and the vegetation dynamics at the intrasesonal scales. Rainfall for instance has been shown to be extremely variable in space over the Sahel with characteristics scales in the order of 20-30 km, event when considering accumulation over the whole rainy season. It stems from this that the operational networks cannot sample the great variability of the seasonal rainfields and that the global rainfall indices supposed to characterise the rainy season are giving an oversimplified image of what the rainy season is. Since many other climatic and environmental variables are dependent on rainfall, this mere fact underlines how important it is to densify, at least locally, the operational networks. Moreover the operational networks of West-Africa are not in an homogeneous state of maintenance and reliability all over the region. For this decadal scale documentation of the climate and the environment AMMA is thus relying on specific observing systems that do not cover the whole region but provide a sampling of the main eco-climatic conditions encountered in West Africa (Fig 1.2). These systems are part of the *Observatoires de Recherche en Environnement* (ORE) program setup by the French ministry of Research. Five such OREs (2 over the ocean, 3 over the continent) were specifically setup in 2001, building on previous observations, some of which started as far back as the 1980's.

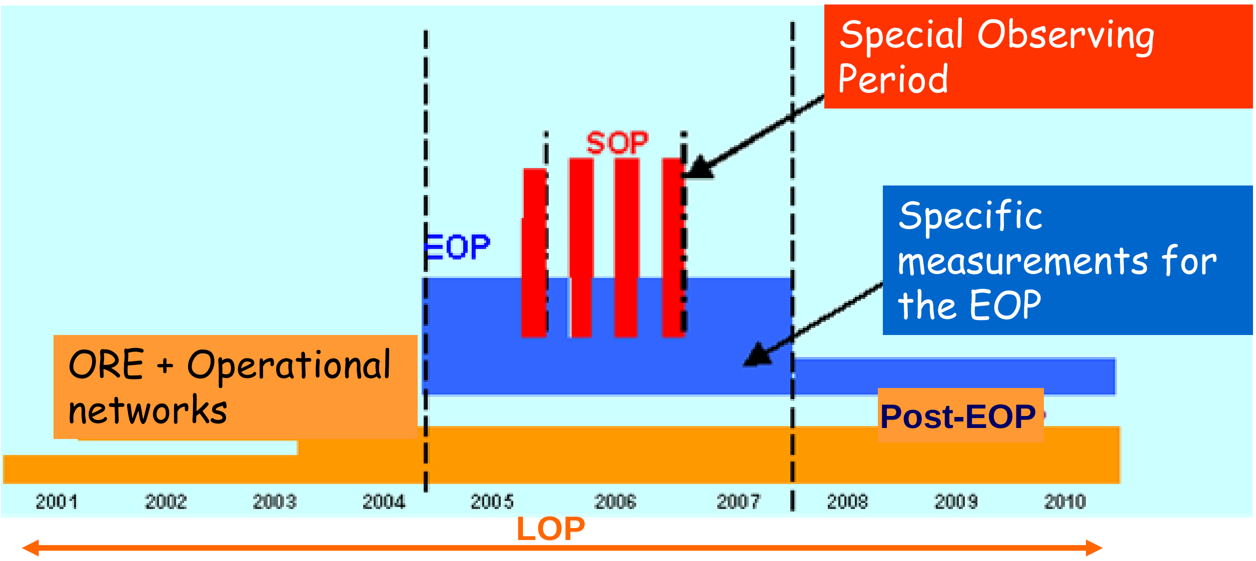

Fig 1.2. The AMMA observing periods.

Table 1.1. Parameters measured by the 5 OREs covering the AMMA region since the early 2000's.

ORE Name	Parameters	Instruments
PIRATA http://www.brest.ird.fr/pirata/	Ocean-atmosphere Fluxes	10 Atlas Buoys
SSS http://www.brest.ird.fr/sss/salinit1.html	Sea Surface Salinity	XBTs and Thermo-Salinographs, since 2003, along commercial routes.
CATCH http://www.lthe.hmg.inpg.fr/catch/	Hydrology, Vegetation	3 mesoscale sites (Gourma, Niamey, Ouémé):

		observations from the mid-1980's and the 1990's. Increased density of measurements from 2001.
IDAF (DEBITS)	Atmospheric Deposits	5 stations in the AMMA region. First installed in 1993.
PHOTONS (AERONET)	Aerosols	8 stations from 2001, 2 additional from 2005

Oceanic OREs (see also maps in Chapter 8, TT6).

PIRATA (http://www.brest.ird.fr/pirata/piratafr.html), 10 atlas buoys in the Atlantic Ocean; 5 are managed by IRD, located at 23°W-0°N, 10°W-0°N, 0°E-0°N, 10°W-6°S and 10°W -10°S; 5 are managed by Brazil, located at 35°W-0°N, 38°W-4°N, 38°W-8°N, 38°W - 12°N and 38°W-15°N.

SSS (Sea Surface Salinity). Based on data provided by commercial ships, this ORE monitors sea profile temperatures (XBT) and sea surface salinity (http://www.brest.ird.fr/sss/salinit1.html and http://www.brest.ird.fr/xbt/xbtorst.html).

Other oceanic international programs of interest to AMMA include the surface drift buoys (SVP) recording SSTs in the framework of the GOOS Global Drift Programme (http://www.aoml.noaa.gov/phod/dac/gcd.html) and the deep drift buoys (PROVOR) providing every 10 days profiles of temperature and salinity in the framework of the ARGO program and its French component CORIOLIS (http://www.ifremer.fr/coriolis/).

Continental OREs.

CATCH: An ensemble of three sites (see Fig. 1.1) devoted to studying the hydrological cycle from the local to the mesoscale and to its coupling with the vegetation dynamics. The three sites are: ***Gourma*** a 25000 km² area in Mali (2°W-1°W; 14°30'N-17°30'N), ***CATCH-Niamey*** a 16000 km² area in Niger (1°40'E-3°E; 13°N-14°N), ***Ouémé*** a 14600 km² catchment in Bénin (1°30'E-2°45'E; 9°N-10°10'N). On Gourma the emphasis is on the vegetation studies with the aim of regional modelling of its dynamics. The two other sites are densely instrumented in hydrological measurements (detailed maps in chapters 5, 6, 7).

IDAF: A network of 5 stations documenting the atmospheric deposits; 3 are installed on each of the CATCH super-site, and 2 are sampling the forest areas (Zoétélé in Cameroon and Lamto in Ivory Coast).

PHOTONS (http://www-loa.univ-lille1.fr/photons/). A transect of 4 Sahelian stations Sal, M'Bour, Ouagadougou, Illorin, plus a station in Morocco (Dakhla), plus one station on each of the CATCH super-site, that is a total of 8 stations. Note that in 2005, a photometer was installed in Cinzana (Mali) and one in Maine Soroa (East Niger), thus enlarging and densifying the Sahelian transect for the 2005-2010 period. Further details may be found in Chapter 4 (TT2b)

Other long term programs of interest to AMMA over the continent include the German GLOWA projects (GLOWA-Impetus on the Ouémé catchment and GLOWA-Volta on the Volta catchment in Burkina-Faso and Ghana), and the Burkina EIER/INRAB Nakambe catchment.

The LOP also involves atmospheric monitoring on the routine synoptic and upper air networks of the region (sounding stations shown in Figure 1.1). Some stations in the region have long and successful climate records, and must be sustained throughout the period, both for direct climatic analysis and to provide consistency in the atmospheric analyses (e.g. ECMWF reanalyses) in which they are assimilated.

2.2.2 EOP

The Enhanced Observing Period (EOP) is designed for a detailed documentation of the annual cycle of the surface and atmospheric parameters for convective to synoptic scales. As such it builds upon the LOP setup and its mesoscale sites strategy associated with a regional monitoring. The enhancement of observations over the mesoscale sites is done at two levels: i) a spatial densification of existing measurements and ii) the installation of instruments allowing for the measurement of variables not observed during the LOP, because these instruments are too costly to operate over such a long period. The regional coverage is obtained through various actions: i) a restoration and upgrade of the radiosounding network operated by ASECNA and national meteorological services; ii) installation of specific new instruments deployed in networks. Added to this continental deployment are oceanic measurements carried out by a research vessel during two annual cruises: one in June and one in September of each EOP year.

As shown in Figure 1.2, some specific EOP instruments will remain in operation after the end of the EOP, which means that there will be more instruments in operation during the post-EOP LOP than during the preliminary 2001-2004 period.

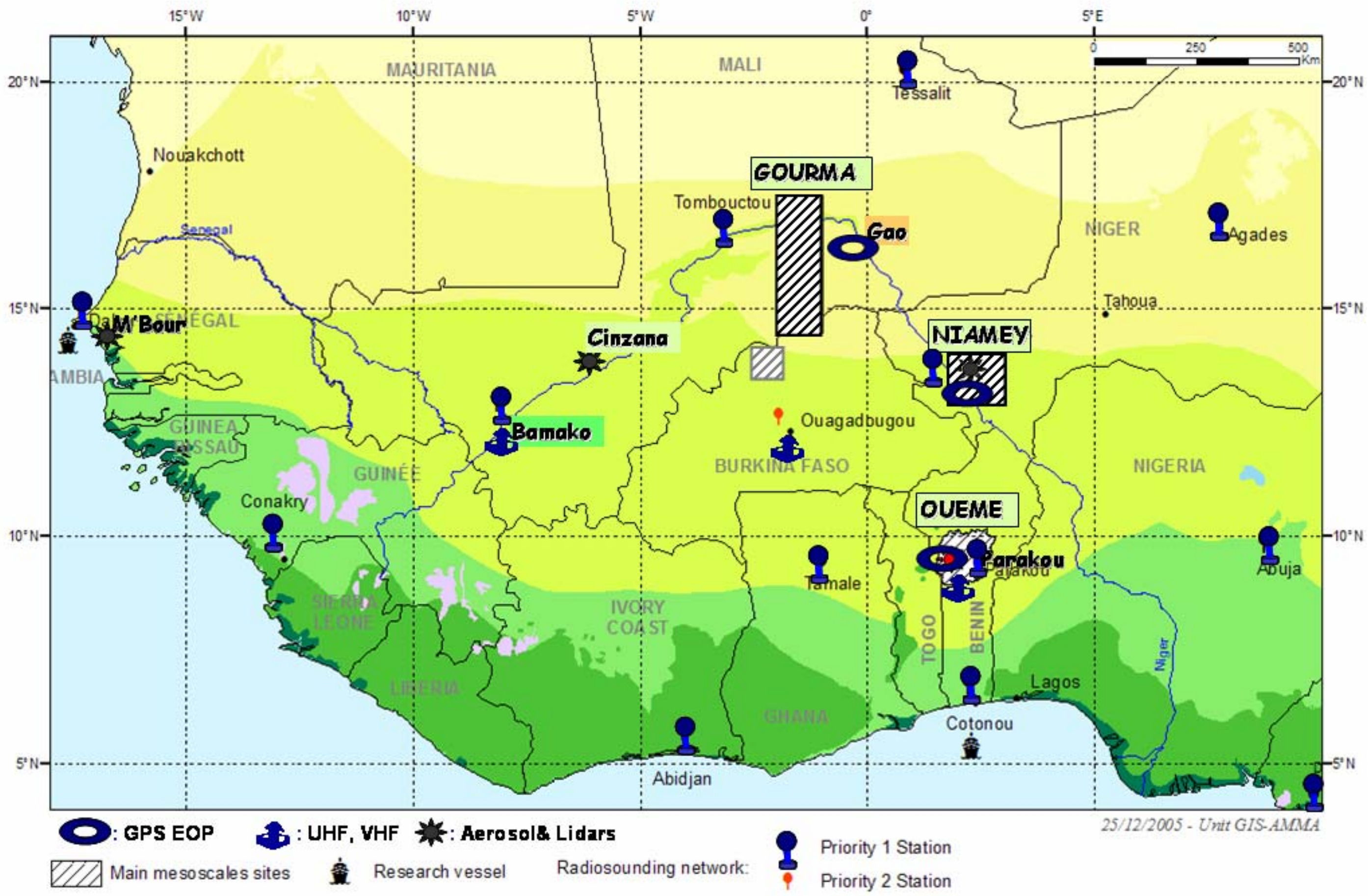

Fig 1.3. The EOP regional observing system on the continent.

2.2.3 SOP

The Special Observing Period, in 2006, focus on the study of processes specific of the main phases of one monsoon cycle, that is: i) the dry phase (phase ***0***) lasting from November to February; ii) the onset phase (phase ***1***) leading to the monsoon jump (end of June); iii) the well developed monsoon (phase ***2***: peak of the rainy season over the Sahel, and little dry season on the coast) from the end of June to mid-September; iv) the period most favourable for the tropical cyclogenesis over the Atlantic, lasting from mid-August to mid-October. This latter period is not a monsoon phase per se and it overlaps phase ***2***. It was identified as a separate period (***3***) because of a specific interest for the Atlantic tropical cyclones that hit the Caribbean and the South-Eastern coast of the USA; phase 3 is also of interest in certain aspects of the aerosol export westwards over the Atlantic. While phases ***0***, ***1*** and ***2*** correspond to well defined regional climatic patterns their exact time frame obviously varies from year to year. Now, the heavy SOP deployment (aircraft and balloons) cannot cover continuously the entire year; thus only a limited part of each phase will be documented by the full SOP setup. These sub-periods are called SOP0, SOP1, SOP2 and SOP3 as shown in Figure 1.4. A number of different platforms and instruments will be deployed in these sub-periods, in different characteristic modes according to their needs and scientific outputs.

Some EOP ground-based networks will be enhanced regionally for a large part of the SOP year – for instance the GPS network and lidar networks will be enhanced in this period. At the same time new ground-based systems will be installed for the SOP year: as an example, the ARM Mobile Facility (AMF) is now installed at Niamey and will operate until 31 December 2006. Other ground-based systems will be installed for sub-periods, according to their scientific priorities (e.g. radars to target precipitation systems in the rainy months of SOP1 and SOP2).

Ships, balloons and aircraft, whose deployments are by necessity relatively short, will be coordinated with the ground-based deployments for specific parts of the SOPs, as illustrated in Fig. 1.5. Within a given SOP, specific aircraft campaigns are defined with a suffix '_a1', '_a2' or '_a3', so that, for example, the second phase of aircraft activity in SOP2, at which we aim to deploy 5 research aircraft in cooperation, is denoted SOP2_a2. The detailed coordination of these instruments is elaborated later in this Implementation Plan.

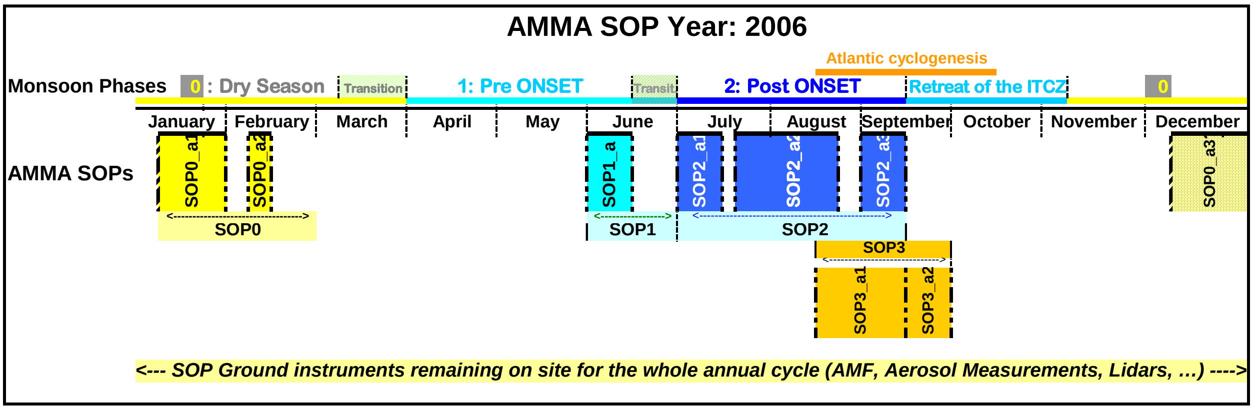

Fig 1.4. The SOP sub-periods

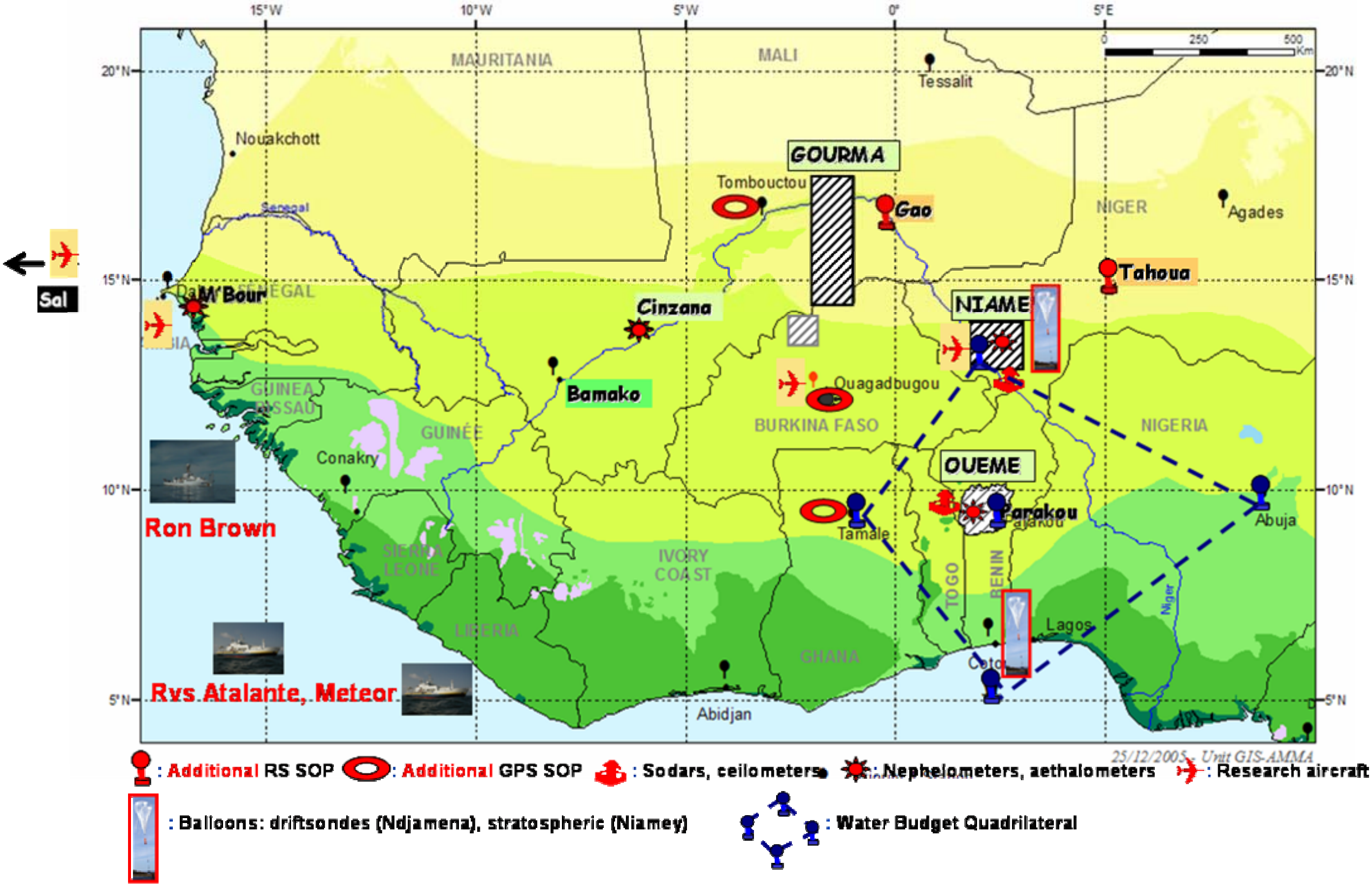

Fig 1.5. The SOP regional observing system. Instruments displayed in red are specifically deployed for the SOP. Note however that not all SOP instruments will be in operation for the whole 2006 year, the deployment of some instruments being limited to a single SOP (see SOP chapters 9 to 11 for details).

3 Presentation of the main AMMA entities

The implementation of the AMMA field programme is coordinated by the International Coordination and Implementation Group (ICIG). This group reports to the ISSC, and is responsible for coordinating the diverse needs of the science teams and instrument teams within AMMA. Given the broad timescales, spatial scales and multidisciplinarity of AMMA, the ICIG has chosen to structure the implementation according to temporal scale, LOP, EOP and SOP as defined above. Following this approach, the implementation is being coordinated by teams whose shared objectives lie in these scales. These teams are termed ‘Task Teams,’ and their remit has been to define coordinated deployment strategies for sets of instruments with shared objectives. There are certain principles which underlie this choice of management structure for the implementation:

- AMMA is a multidimensional and multidisciplinary programme, and it is imperative that communication between Task Teams, and an effective overall vision of the implementation is not lost. It is the role of the ICIG, reporting to the ISSC, to hold this integrative vision of the programme.
- Every instrument is managed by at least one Task Team.
- Some instruments with different modes of activity (e.g. radiosondes) may be managed by more than one Task Team.
- The work of the task teams is a continuous process of refinement of strategy, which will evolve during the months leading to the actual deployment, and which includes ‘responsive’ strategy

during the deployment (for instance, the SOP Task Teams are responsible for flight-planning). However, the work of the Task Teams is time-limited: following the respective periods of deployment, the Task Teams will not be required and the responsibility for coordination of data use will lie with the AMMA Working Groups (WGs), which report to the ISSC.

Table 1.2. The AMMA task teams

TT#	TT Name	Time and Space Scales	Type of sampling
TT1	EOP Sounding of the Atmosphere	EOP; Regional	Homogeneous over the whole sub-continent, plus transects
TT2a	EOP Surface Flux Measurements	EOP; Regional to local scale	Concentration on meso-scale sites, plus station to the South
TT2b	EOP/LOP Aerosols Monitoring and radiation	LOP/EOP; Regional	Sahelian transect & Super-sites
TT3	EOP/LOP integrative studies on the Gourma meso-scale site	LOP/EOP; Mesoscale to local scale	1x1 km² "plots" distributed all over the study area
TT4	EOP/LOP integrative studies on the Niamey meso-scale site	LOP/EOP; Mesoscale to local scale	Homogeneous sampling at the mesoscale with denser networks on a super-site
TT5	EOP/LOP integrative studies on the Ouémé meso-scale site	LOP/EOP; Mesoscale to local scale	As in TT4, except for one additional minor super site
TT6	EOP/SOP Oceanic campaigns & measurements in open ocean	EOP/SOP; Regional (Ocean)	Cruises following "rails".
TT7	Dry season SOP	SOP; Regional to mesoscale	Intensive observations using aircraft & ground instruments
TT8	Wet season SOP	SOP; Regional to mesoscale	Intensive observations using aircraft, balloons & ground.
TT9	Downstream SOP	SOP; Regional/ Downstream	Intensive observations using aircraft, & ground instruments

In addition to the AMMA Task Teams, certain ‘Support Teams’ (STs) have been defined, in areas where an aspect of the implementation crosses the temporal and disciplinary boundaries of the Task Teams (e.g. ST3, the database team).

It should be made clear that support teams do not provide resources for AMMA scientists, but exist as a coordination tool for different groups with similar needs. For example, ST2 (SOP Logistics) exists as a forum between the numerous groups who are coordinating the logistical needs of instruments in Africa, so that resources can be shared and good practice can be disseminated.

Table 1.3. The AMMA support teams

ST#	ST Name	Function
ST1	EOP logistics	Inventories and synthesises the EOP TTs needs and interacts with the AMMA Operation Centre to determine how these needs can be satisfied. Evaluate the associated cost and human resources.
ST2	SOP logistics	Inventories and synthesises the SOP TTs needs and interacts with the AMMA Operation Centre to determine how these needs can be satisfied. Evaluate the associated cost and human resources.
ST3	Data base	Meta data base, data base, data policy.
ST4	Fund raising, capacity building and training	In charge of raising funds for AMMA-Africa, making AMMA known to international funding agencies and program with the aim of attracting funding to the African institutions and scientists involved in AMMA. Organises summer schools, training sessions, field schools, workshops. Centralises opportunities for training in University programs in Europe or USA.

4 Sites and Instruments.

The AMMA field program relies on operational networks and on instruments specifically deployed on various sites for periods of varying duration, as described above. In this section we first provide an overview of the sites (see also maps 1.1, 1.3 and 1.5) and platforms on which instruments are deployed; then two tables summarise the instruments in operation during the three main AMMA periods. More details can be found in the TT chapters and in appendix.

4.1 Sites and Platforms

4.1.1 Ground Sites

Table 1.4. The regional scale windows and transects

Name	Position	Description	Periods of activity
Continental Regional Window	4°N -21°N; 18°W-10°E	The whole continental area of interest. The monitoring is based on the operational networks (Radio-sounding stations, Synoptic stations, Raingauge national networks). IDAF and PHOTONS networks*. Remote sensing plays a major role.	2001-2004 2005-2007 2008-2010
Sub- Regional Window	5°N -18°N; 0-4°E + 11°N -18°N; 2°W-0° 780,000 km²	Includes the three main mesoscale sites, plus the ancillary sites of the Nakambe and Dano in Burkina Faso.	2001-2008
Sahelian Transect	M'Bour, Cinzana, Banizoumbou	Aerosol (3 stations) studies during EOP and post EOP; Convective systems studies (radars during SOP), including their role in dust transport	2005-2007 2008- ? 2006
Water Budget Quadrilateral South	Cotonou, Tamale, Niamey, Abuja	Water budget closure studies during the SOP year	2006

* Note that the IDAF network extends to Zoetele 3°N,11°E (Cameroun) and PHOTONS include one station in Morocco.

Table 1.5. The mesoscale sites

Name	Position	Description	Period of activity
Ouémé Catchment	Bénin; 9°-10°N; 1.5°-3°E 14200 km²	Densely instrumented catchment with denser instrumentation on sub-catchments (Donga, Aguima, Ara). Soudanian climate (different types of rain systems) and Savannah vegetation. Global models; impact of climate variability on water resources.	1997-2007 + post EOP monitoring
Niamey meso-site / Kori de Dantiandou	Niger; 13°-14°N; 1.6°-3°E 16000 km² / Catchment in the North-East of Niamey meso-site 5800 km²	The survey of the “Niamey square degree” started in 1990. Heavy observations in 1992, monitoring from 1994 to 2002, densification starting again in 2003. Sahelian climate with semi-arid vegetation (Millet crops, Tiger bush,…). Long series of high resolution rain data and groundwater levels.	1990-2008 + post EOP monitoring
Gourma	Mali; 14.5°-17.5°N; 2°-1°W 30000 km²	Sahelian to saharo-sahelian climate (between isohyets 400 and 100 mm). Semi-arid natural vegetation composed of annual grasses and a sparse tree layer. Crops only present in the southern part of the area. 16 vegetation sites monitored since 1984. Also satellite products validation sites (vegetation, soil moisture).	1984-2008 + post EOP monitoring
Nakambé	Burkina; 14.1°-10.9°N; 2.5°-0.1°W; 40836 km²	Sahelian climate (between isohyets 400 and 100 mm). Semi-arid natural vegetation. Hydrological monitoring, erosion studies.	2004-2009

Table 1.6. Super sites

Name	Position	Description	Period of activity
Donga Catchment	Bénin; 9.6°-9.9°N; 1.6°-2°E 590 km²	Sub-catchment of the Ouémé catchment with a dense recording raingauge network (14 stations) and 5 streamflow stations. Land surface process studies, hydrological modelling, coupling with the sub-surface and the atmosphere.	2002-2008 + post EOP monitoring
Aguima Catchment	Bénin; 9.10°-9.14°N; 1.9°-2°E, 30 km²	Sub-catchment of the Ouémé catchment, with a dense recording raingauge network (9 stations, some are in neighbouring catchments) and 5 water level recorders, 3 weather stations. Evaporation and soil	2001-2008 + post EOP monitoring

		moisture measurements. Land-surface process and agricultural studies; hydrological modelling.	
Niamey Super- Site	Niger; 2°35’-2°48’; 13°25’-13°45’, 600 km²	Kori de Dantiandou and adjacent areas. Dry vegetation cover. Land surface process studies, hydrological modelling, coupling with the sub-surface and the atmosphere. Rainfall vs vegetation spatial relationship, at the local scale	1991-2008 + post EOP monitoring
Titao Catchment	Burkina Faso; 13°40'-14°N, 2°-2°2' W < 50 km²	Sub-catchment located in the north of the Nakambé basin. Hydrological, erosion, bio climatic, environmental, soil physics and vegetation dynamics studies. Water, matters (solid and dissolved) and energy flux. Three different soil surface types (bare soils, cultivated lands and natural vegetation covered surfaces).	2004-2009
Dano	Burkina Faso, 11.15°N, 3.07°W, 20km²	Sudan Savannah, dam at outlet of subcatchment/testsite, micrometeorological system and various devices for C/N/H2O turnover	2005-2007

Table 1.7. AMMA local intensive sites

Name	Position	Description	Period of activity
Ara Catchment	Bénin; 9.9°N; 1.6°E 14 km²	Sub-catchment of the Donga and Ouémé catchments. Geophysical and geochemical studies. Flux measurements. X-Band radar and disdrometer. Emphasis on process studies	2003-2008
Banizoumbou	Niger (13°31’30’’N, 2°38’21’’E)	Ground based measurement of aerosols properties (physico-chemical, optical) and dust fluxes measurements. Weather station. Local water budget.	1991-2008
Wankama	Niger; 1,8 km²	Flux measurements ; Soil moisture; local recharge	1991-2008
Hombori-Agoufou	Mali; 15.2°N, 1.3°W 1 km²	Sand dune site with a sparse tree cover. Annual rainfall : 370 mm (1920-2003). Vegetation and soil moisture measurements. Automatic Weather Station. Flux measurements. Sun photometer. Validation of satellite products. Vegetation modelling.	2002-2008
Tougou Catchment	Burkina Faso; 13°40'39" N, 2°13'41" W 36 km²	Sub-catchment located in the north of the Nakambé basin. Hydrological, erosion, bio climatic, environmental, soil physics and vegetation dynamics studies. Particle transport (solid and dissolved) and energy flux. Three different soil surface types (bare soils, cultivated lands and natural vegetation covered surfaces).	2004-2009

Table 1.8. Other Local sites of interest to AMMA

Name	Position	Description	Period of activity
Dahra (Ferlo Region)	Sénégal 15° 49' 09.012" N 15° 03' 39.118" W	Sahelian climate (300-450 mm rain) with semi-arid savannah vegetation. Annual grasses with a maximum height of 60 cm. Tree and shrub canopy cover generally < 5 %. Pastoralism is the dominant activity, but rain-dependent cultivation is an important secondary land use. Livestock are present year-round	2005-2008
Lamto	Côte d'Ivoire	Wet and dry atmospheric deposition. Vegetation studies	1991-2008

4.1.2 Aircraft and Balloons

Table 1.9. Aircraft characteristics

	BAe-146 G-LUXE	ATR-42 F-HMTO	Falcon F-GBTM	Falcon D-CMET	Geophysica 55204	DC8 NASA
Weight	44.2 t	16.9 t	14.5 t	13.8 t	24.6 t	
Wingspan	26.34 m	24.57 m	16.32 m	16.32 m	37.46	
Length	31 m	22.67 m	17.15 m	18.75 m w. Noseboom	22,87	
Height	8.61 m	7.59 m	5.32 m	5.37 m	4.83	
Take off field length	1600 m	1200 m	1400 m	1830 m	>2000 m	
Max. Payload	4 t	4.6 t	1.2 t	1.65 t	2.25	
Scientific Payload, normal config.	4 t	2.5 t	1.0 t	1.20 t	1.5 t	
Maximum Endurance	6 hours	5 hours	5 hours	4,6 hours	5.5 hours	
Endurance in AMMA config.	5 hours	3.5 hours	4 hours	4,0 hours	4.5 hours	
Max cruising speed	796 km/h	490 km/h	871 km/h	917 km/h	720 Km/h	
Scientific cruising speed	220-780	250-470		740 km/h	250 – 720	
Max. Range scientif. Config.	3200 km	1200 km	3220 km	2780 km	2800 Km	
Max. Range opt. conditions	3700 km	2000 km	4100 km	3200 km	3300 Km	
Logistics						
Flying Crew/ Equipage en vol	21	11	6	5-6	1	
Ground Crew/ Equipe au sol	6	3	3	3	15	
Fuel Weight (Jet A-1)	2800 l/h	3500 l	4130 kg	4006 kg	7600 kg	
GPU / Unité auxiliaire au sol	60 kva	28 kva	28 kva max 285 A	28 kva max 600A	35 KVA	
Air Control						
Low level flight	250' AGL	150' AGL	**N**	500´ AGL	**N**	
Dropsondes	**Y**: clearance	**N**	**Y**: clearance	**N**	**N**	

Table 1.10. Aircraft deployement in SOP 1 (1st June- 15th June) and SOP2 (1st July- 15th September).

Dates (weeks) / Aircraft	29/5	5/6	12/6	19/6	26/6	3/7	10/7	17/7	24/7	31/7	7/8	14/8	21/8	28/8	4/9	11/9	18/9
Bae 146 (UK)								17Juil. - 21 Aout					22-28/8				
ATR 42 (FR)	1er - 15 Juin					1er-15 Juil.				25 Juil. -25 Aout							
F20 (FR)	1er - 15 Juin					1er-15 Juil.				25 Juil. -25 Aout					1er-15 Sept		
F20 (D)						1er-15 Juil.					31/07 -18/08						
M55(EU)											31/07 -18/08						

from Niamey (Niger)
from Dakar (Senegal)
from Ouagadougou (Burkina Faso)

In addition to the aircraft listed in the table above, there is the possibility of including in the AMMA deployment the Skyvan from Helsinki University of Technology (HUT) equipped with the EMIRAD radiometer, operating from Niamey and/or Gao airport. The Skyvan has short take off and landing capabilities (typically take off distance of 700m at sea level in standard conditions). The funding of this aircraft is not yet secured at that time.

Table 1.11. Balloons requiring flight clearances

	BPCL	Drif-Sondes (SBDS)	Stratospheric balloons
Poids - Weight Envergure – Wingspan Hauteur - Height Aire de lancement/ Launching Pad Endurance Max. Range envisioned for AMMA	 2.5 m 2.5 ..m 30 x 30 m 15 days	 12 m 27 m 100 x 100 m 15/20 days	 30 m 70 m 100 m x 100 m 6 hours 400 km
Measured Parameters/ Paramètres	Coordinates + P, T, RH	Coordinates + P, T, U, RH	Coordinates + P, T, U, RH, chemistry
Logistics Ground Crew/ Equipe au sol: Science Ground Crew/ Equipe au sol: Technic.	 2 4	 4 11	 27 15
Air Control Identification Flight –Altitude- de Vol Dropsondes	 flashlight 850-900 hpa **N**	 Radar transponder, flash-lamp, Radar reflector 50/60 hpa **Y**: clearances	 Radar transponder, flash-lamp, Radar reflector 15000-30000 m **N**
Deployment / Déploiement SOP1 (1 – 15 Juin) SOP2_a1 (1-15 Juillet) SOP2_a2 (20 Juillet-20 Août) SOP3	 Cotonou Cotonou	 N'Djamena, about 5 launchings N'Djamena, about 5 launchings	 Niamey, about 15 launchings

4.1.3 Research Vessels

Table 1.12. RVs characteristics

Measurements \ cruises	Suroît (EOP)	Atalante (SOP)	Ron Brown (SOP)	RV Météor SOP***	ITAF DEME SOP
Hydrology (CTDO2)	YES	YES	YES	YES	YES*
Currents (S-ADCP and/or L-ADCP)	YES	YES	YES	YES	NO
Continuous SST and SSS (TSG)	YES	YES	YES	YES	NO
Temperature profiles (XBT)	YES	YES	YES	NO	YES*
Salinity profiles (XCTD)	YES	YES	NO	NO	NO
Surface drifters deployment (SST)	YES**	YES**	YES	??	??
Surface drifters deployment (wind & sea level pressure)	YES**	YES**	YES	??	??

Table 1.12 (followed). RVs characteristics

ARGO profilers deployment (T&S profiles)	YES	YES	YES	YES	YES*
Sea water samples for analysis (S, O2, and nutrients)	YES	YES	YES	YES	YES
Ocean microstructures (turbulence)	YES ***	YES ***	??	YES	NO
Helium (air and ocean) for upwelling rate estimate	partly ****	YES ****	NO	YES****	NO
Meteorological measurements (classical station -eg BATOS-)	YES	YES	YES	YES	YES
Atmospheric microstructures & air sea fluxes (turbulence)	NO	YES	NO	NO	NO
Radiosoundings (from vessel)	NO	YES	NO	YES	NO
Sea water samples for analysis (O18, 13C & CO2 parameters)	YES	YES	NO	YES	NO
Aerosol (photometer)	YES	YES	NO	NO	NO
Drifting vertical temperature profiles (MARISONDE)	NO	YES	NO	NO	NO

*: provided and/or funded by (or in the framework of) AMMA-France (API)
**: provided and/or (maybe partly) funded by (or in the framework of) AMMA-US (NOAA)
***: provided and funded in the framework of German CLIVAR-TACE contributions (IFM-GEOMAR)
****: provided and funded in the framework of German SOLAS contribution (University of Bremen)

4.2 Instruments

An AMMA instrument is defined as a sensor or set of sensors allowing for a coherent spatio-temporal sampling of a geophysical variable or of a set of inter-related variables with respect to the study of a given process. Following are a few broad types of instruments:

- Isolated station making point measurements (ex : a meteorological station).
- Network of stations allowing for a coherent spatio-temporal sampling on a super-site or a meso-scale site (typically a raingauge network, soil moisture measurement sites, a set of vegetation plots, an ensemble of similar flux stations), or possibly at the regional scale (Photometres Network, GPS Network, buoys Network).
- Isolated instrument making spatially integrated measurements and/or with a large spatial coverage (typically a radar).
- A set of co-located instruments (aerosol, local water fluxes, aircraft instrumentation).
- Mapping Campaigns (vegetation, geophysics).

A complete list of all the instruments deployed in AMMA is given in appendix. The table below provides a synthetic overview of this deployment. Note that the details of the deployment in the framework of SOP3 are still not fully known, some funding issues being still not decided.

Table 1.13. Summary of EOP and LOP instruments. Many instruments agglomerate several sensors, so the total number of sensors corresponding to the 41 EOP instruments is in the order of a few hundreds.

Type of instruments	Number of inst. Deployed (EOP – LOP)	Scale (or sites)	TT
RS networks, GPS network, Ozone sounding	5 – 0	Regional	1, 5
Met. Radars, UHF, VHF	3 – 0	Djougou (Rad. X, VHF) Bamako, Ouaga (UHF)	1, 5
Flux and Met. Station (isolated or in networks); disdrometers	7 – 7	3 Mesoscale sites, most often on super-sites	2a, 3, 4, 5
Other Flux measurements (Balloon, Scintillometer)	2 – 0	Hombori, Djougou	2a, 3, 5
Aerosols	2 – 1	Sahel Transect + Lamto	2b, 5
Nox	2 – 0	Hombori, Djougou	3, 5
Hydrological and vegetation monitoring networks	4 – 2	Gourma Mesoscale site	3
Hydrological and vegetation monitoring networks	7 – 4	Niamey Mesoscale site	4
Hydrological and vegetation monitoring networks	6 – 6	Ouémé Mesoscale site	5
Buoys (XBT, CTD, ..)	3 – 6	Regional (Ocean)	6
TOTAL	EOP: 41 LOP: 26		

Table 1.14. Summary of SOP ground instruments.

Type of instruments	Number of inst. Deployed	Scale (or sites)	TT
RS & GPS networks, RS on the ocean, Ozone sounding	7	Regional	1,5, 6, 8
Balloons: BVC and Drift	2	Cotonou & N'djamena	8
Radars, Profilers, Sodars	9	Dakar, Niamey, Djougou	8, 9
Other Flux measurements (Balloon, Station)	2	Niamey, Dano	8
Aerosols: Lidars	4	SS + M'Bour + Tamanrasset	2b, 7, 8
Aerosols & Chem.: Nephelo., Aethelometers, TMS, Impactors	4	Super-sites	2b, 7, 8
Collection of Met., Flux, Profile and Radiometric measurements	12	Niamey and Banizoumbou	ARM Mobile Facility
Chemistry	1	Djougou	8
Met. And Fluxes on the Ocean, Buoys (XBT, CTD, ..)	5	Regional (Ocean)	6
Miscellaneous (Lightning, (	1	Djougou	8
TOTAL	**47**		