4.2 Field experiments

Coordination : T. Lebel

4.2.0 Vue d'ensemble

La stratégie d'observation d'AMMA se définit en terme d'échelles spatiales et temporelles (cf Chapitre 0 de la proposition). Dans le domaine temporel, on a identifié trois périodes par référence à la densité des observations spécifiques envisagées : LOP, EOP, SOP. Pour bien comprendre comment s'est construit – de manière progressive – cette stratégie, il faut en fait discerner cinq phases : i) la période préliminaire des années 1990 : le projet AMMA n'existe pas encore, mais les éléments de son émergence se situent à cette époque ; ii) une phase préparatoire (2001-2004) au cours de laquelle la stratégie d'observation se précise graduellement et les mesures de terrain sont mises en place ; iii) l'EOP (2005-2007), qui inclut iv) la SOP de 2006 ; v) une phase de suivie post-EOP (2008-2010 ?) au cours de laquelle la priorité sera donnée à la gestion des retombées pour les pays africains (voir schéma ci-dessous).

Dans l'espace on distingue quatre échelles allant du sous-continent ouest-africain (échelle régionale incluant le proche océan) à l'échelle convective (ou locale) en passant par une échelle sous-régionale et la méso-échelle. L'échelle globale est prise en compte par le biais des observations satellitaires et la modélisation ; elle ne fait pas l'objet d'observations spécifiques de terrain mais AMMA s'intègre dans une stratégie globale d'observation du climat et du système terrestre orchestrée notamment dans le cadre des composantes GEWEX et CLIVAR du PMRC, DEBITS d'IGAC et AERONET.

Entre une stratégie idéale – qui consisterait à instrumenter de manière homogène dans le temps et dans l'espace un certain nombre de sites couvrant le continuum climatique et les éco-systèmes – et la stratégie finalement adoptée, se situe un ensemble de contraintes humaines, opérationnelles, matérielles et financières. A bien des égards la stratégie d'observation de AMMA diffère de celles habituellement utilisées dans les expériences météorologiques. Les périodes d'observation hors-SOP ne consistent pas *seulement* ici à fournir des compléments sur l'environnement de la SOP : plusieurs objectifs de AMMA imposent que les périodes d'observation pré et post SOP possèdent leur propre logique, l'exercice consistant alors à ce que l'ensemble soit le plus cohérent possible.

4.2.0.a Les phases du projet

Période d'avant-projet (1990-2000)

Plusieurs systèmes d'observations ont vu le jour au cours de cette période, essentiellement à des fins de recherche mono-disciplinaire : l'observatoire du Gourma Malien (1985) dédié aux observations de végétation dans un milieu pastoral semi-aride ; le degré carré de Niamey (1990), point d'appui de l'expérience HAPEX-SAHEL (1991-1992), sur lequel un suivi fin de la pluviométrie, du bilan hydrologique de certaines mares et de la recharge des aquifères a été réalisé ; le réseau IDAF de suivi des dépôts d'espèces chimiques, dont la première station a été installée à Lamto en 1990 ; le réseau PHOTONS (première station installée à Banizoumbou en 1995) mesure différents paramètres liés au transport d'aérosols (épaisseur optique, coefficient d'Angstroem, granulométrie des aérosols en suspension entre 0,1 et 30 µm en diamètre), ainsi que le contenu intégré en vapeur d'eau ; le bassin du Haut-Ouémé (1997) formant avec le degré carré de Niamey l'observatoire hydrométéorologique CATCH.

Parallèlement le projet européen WAMP, dédié aux études de modélisation atmosphérique de la mousson ouest-africaine, mettait en évidence un déficit d'observations atmosphériques et de surface pour pouvoir progresser dans la modélisation couplée des différentes composantes de ce système climatique.

Il s'est ainsi formé, en France mais aussi en Europe, une communauté multidisciplinaire dont le rassemblement a permis l'écriture en 2000 d'un livre blanc sur la mousson africaine. Les grandes questions scientifiques à traiter et des éléments de stratégie d'observation pour obtenir les données nécessaires ont été récapitulés dans ce livre blanc, qui a servi de base pour l'écriture du plan scientifique international de AMMA.

Phase préparatoire (2001-2004)

Au cours de cette phase, l'accent a été mis sur la création de cohérences entre les différents systèmes d'observation pré-existant et de liens avec les mesures – historiques et en cours – des réseaux opérationnels. Il s'agit donc d'un amalgame d'observations spécifiques à AMMA, d'observations menées à des fins de recherche dans un cadre antérieur à AMMA et d'observations opérationnelles. Ce dispositif concerne surtout les surfaces continentales. Les sites de méso-échelle ont été considérablement renforcés au cours de cette période et plusieurs super-sites ont été mis en place. Le lancement de la procédure ORE par le ministère de la recherche, a grandement contribué aux acquis de cette période. Trois systèmes d'observation formant le noyau de la LOP de AMMA sur les surfaces continentales ont été labellisés ORE : AMMA-CATCH, IDAF, PHOTONS. L'ORE AMMA-CATCH regroupe les deux sites de l'observatoire CATCH et le site du Gourma malien. Les réseaux IDAF et PHOTONS se sont partiellement redéployés pour installer des stations sur les super-sites AMMA-CATCH (voir carte de la figure 1.3 de la section introductive à ce document API).
Concernant les surfaces océaniques, les observations disponibles reposent soit sur des campagnes ponctuelles spécifiques effectuées dans le cadre de programmes internationaux (CLIVAR ; ex : EQUALANT, PIRATA) soit sur des systèmes de réseaux opérationnels de mesure, dont deux ont été également labellisés ORE en 2003 : PIRATA et SSS. PIRATA est un programme tripartite entre le Brésil, les USA et la France, qui consiste à maintenir un réseau de 10 bouées de mesures météo-océanographiques, de type ATLAS, en Atlantique Tropical, et SSS est un programme consistant à collecter des mesures de salinité de surface de l'océan (SSS=Sea Surface Salinity) à partir des navires océanographiques mais aussi de navires marchands spécialement équipés en thermosalinographes. Des profils thermiques sont également obtenus grâce à ce réseau. Il faut également mentionner le projet CORIOLIS, initialisé en 2000, consistant à récolter toutes les mesures réalisées « en route » (température, salinité, courants, profils thermiques…) et qui peuvent être transmises en temps quasi-réel à partir des navires en mer, soit lors de campagnes, soit en transit.
Un bilan des équipements réalisés dans le cadre des ORE sur la période 2002-2004 est donné dans un tableau en annexe de la section 4.2.3 dédiée à EOP-LOP. De nombreux travaux d'analyse des données recueillies sur ces deux phases préliminaires ont été publiés (voir liste bibliographique en annexe).
Il est à noter que le dispositif ORE est en fin de phase initiale et va être repensé, à travers un exercice de prospective auquel les ORE « AMMA » doivent contribuer. Cette mutation des ORE est en phase avec l'entrée de AMMA en période EOP (2005).
Outre les observations proprement dites, la phase préparatoire a permis de mener des missions de reconnaissances, de cartographier la zone d'étude, d'acquérir des éléments de climatologie, de faire des premières estimations de bilan d'eau de surface et d'équiper des super-sites.

EOP (2005-2007)

Dans le prolongement de la phase précédente l'EOP va permettre de continuer à documenter sur plusieurs années le cycle hydrologique et la dynamique de la végétation associée, à étudier les impacts associés et les rétro-actions d'échelle régionale ou méso ; de plus, l'observation pluri-annuelle accroît la probabilité de pouvoir observer certaines situations extrêmes (cas de le pluie centennale de Niamey en 1998). Le renforcement des observations durant l'EOP vise deux objectifs supplémentaires : i) documenter finement des échelles de variabilité non accessibles à la SOP (cycle saisonnier sur l'ensemble de la région, variabilité interannuelle, processus de rétro-action avec les effets mémoire associés) et ii) fournir un cadre pour la SOP (étude des sites, environnement climatique et hydrologique, préparation opérationnelle).

SOP (2006)

La SOP répond à des besoins bien cernés pour traiter certaines composantes océanographiques et atmosphériques – dynamique, chimie et aérosols– clefs du système de mousson. Les moyens intensifs déployés (sol, avions, bateaux) garantissent une bonne couverture mais en limitent la durée, du fait des coûts associés. La SOP a été découpée en 4 grandes périodes auxquelles correspondent des grands objectifs. Deux remarques importantes sont à prendre en considération :

i) les contours exacts de la SOP3 sont encore en cours de définition car si la partie qui peut être considérée comme le prolongement direct de la SOP2 est supportée par AMMA-France et AMMA-IP (qui est référencée parfois comme SOP2b) , la partie cyclogénèse (ou downstream) n'aura lieu que si des moyens conséquents et en cours de discussion sont mis en œuvre par les USA

ii) il y a une continuité dans le temps entre SOP1, SOP2 et SOP3 même si les régimes dynamiques ne sont pas les mêmes et donc les objectifs scientifiques différents.

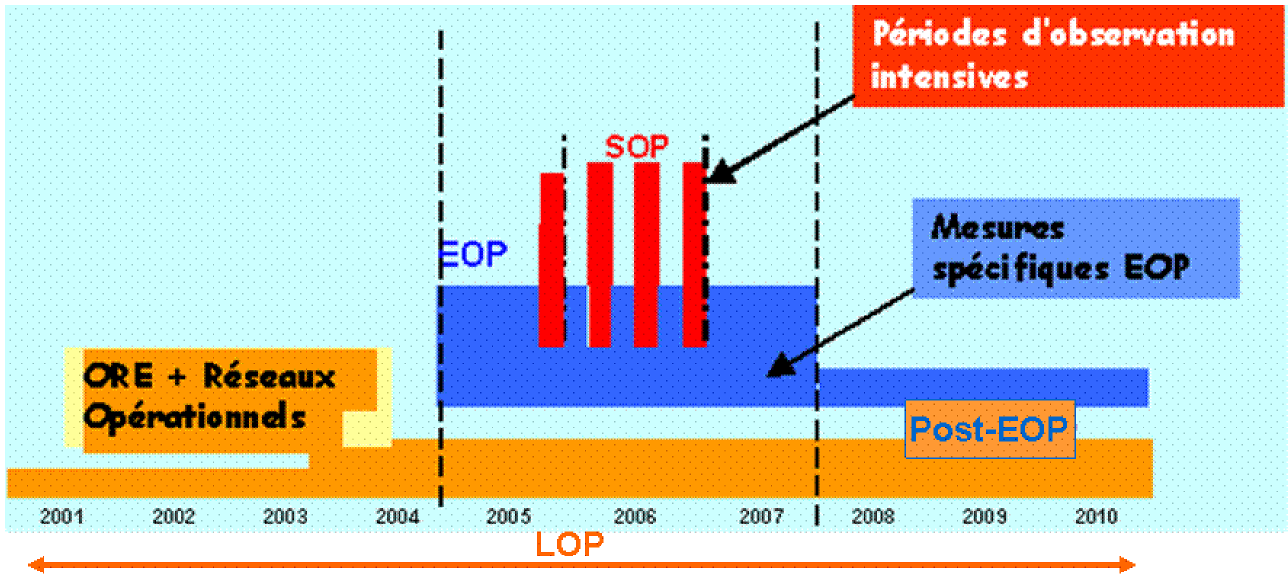
Les grands objectifs de la SOP sont :

- SOP-0 "Dry Season and aerosols" January-February 2006 to measure aerosol properties (physical-chemical and optical properties) to characterize dust and biomass burning aerosols and their variability over dust production areas and in the vicinity of fires
- SOP-1 "Monsoon Onset" May-July 2006 to investigate the structure and evolution of the atmospheric and oceanic boundary layer and tropospheric jets before and during the arrival of the monsoon flow and to quantify the water, energy, aerosol and trace gases budgets.
- SOP-2 "Monsoon Maximum" July - mid August 2006 to investigate the propagation and evolution of precipitating systems including their interactions with synoptic scales, to measure the chemical components in the tropical tropopause layer zone and to study aerosol, clouds and radiative effects
- SOP-3 "Late Monsoon" mid- to end of August 2006 to study the transformation of the meso- to synoptic scale perturbations as they propagate over the West African continent to the warm waters of the tropical eastern Atlantic, to investigate the ice phase microphysics properties of MCS anvils, to study the influence of environmental conditions, particularly the presence of dry saharan air in the mid-troposphere; to measure the large-scale transport of chemical components and aerosol.

Phase de suivi post EOP (2008-2010)

Le dimensionnement de la phase de suivi post-EOP dépendra de plusieurs facteurs : engagement des organismes français derrière le dispositif ORE, implication des partenaires institutionnels africains (régionaux et nationaux), à travers le projet européen, le FSP RIPIECSA et d'autres mécanismes de soutien à la recherche en Afrique. L'équipement LOP et EOP étant destiné pour sa plus grande partie à rester en Afrique, son utilisation par des équipes bien formées au cours de l'EOP pourrait permettre un bon suivi post EOP dans plusieurs domaines : cycle de l'eau continental, dynamique de la végétation, aérosols, dépôts d'espèces chimiques.

Le renforcement des réseaux opérationnels (stations de radio-sondage et les réseaux synoptiques de certains pays) devrait également permettre un meilleur suivi météorologique à l'échelle régional pour les années post-EOP.



Périodes d'observation intensives
SOP
EOP
Mesures spécifiques EOP
ORE + Réseaux Opérationnels
Post-EOP
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
LOP

4.2.0.b Domaines couverts

Le domaine régional

Intégration des différents ensembles sous-régionaux , mesures océaniques, importance de l'intégration avec les mesures satellitaires et la modélisation.

Les dispositifs sous-régionaux

Les dispositifs sous-régionaux tiennent compte de : i) l'existence de sous-domaines climatiques tels que la zone sahélienne au nord de 10°-11°N (faible influence de la première saison des pluies, mise en place de la saison des pluies lors du saut de mousson, prédominance des gros systèmes convectifs mobiles dans la production de la pluie) et la zone au Sud de cette limite ; ii) des limitations pratiques qui font qu'il est impossible de couvrir l'ensemble de l'Afrique de l'Ouest d'un tissu homogène d'observations que ce soit en LOP, EOP ou SOP. AMMA s'appuie sur cinq dispositifs sous-régionaux :

- La partie océanique du domaine régional.
- Le transect sahélien qui inclut le réseau aérosols *PHOTONS*, un ensemble de 3 stations de suivi des aérosols terrigènes, un ensemble de 5 stations de radio-sondages et un réseau potentiel de trois à quatre radar météorologiques susceptible de permettre un suivi des lignes de grains depuis le Sahel central jusqu'à l'océan atlantique.
- Une fenêtre couvrant le continuum climatique du golfe de Guinée au Nord du Sahel et délimité par les stations de radiosondage d'Abidjan, Bamako, Tombouctou, Agadez, N'Djamena, Douala, Cotonou). Cet hexagone couvre les trois sites de méso-échelle *AMMA-CATCH*, le bassin de la Volta étudié par nos collègues allemands du projet *GLOWA-Volta* et le bassin du Niakambé, étudié par nos partenaires burkinabais de l'EIER.
- Un quadrilatère sud de radiosondages (Cotonou, Tamale, Niamey, Mina, plus Parakou au centre) établi pour l'étude des bilans d'eau, centré sur le site de méso-échelle du haut-bassin de l'Ouémé, qui fonctionnera en EOP.
- Un quadrilatère nord de radiosondages (Parakou, Ouaga, Tombouctou, Tahoua) établi pour l'étude des bilans d'eau, centré sur le site de méso-échelle du degré carré de Niamey, qui fonctionnera uniquement en SOP.

Les sites de méso-échelle

Trois sites de méso-échelle (Gourma et Degré de Niamey au Sahel, Haut Bassin de l'Ouéme en zone soudanienne) feront l'objet d'un suivi sur toute la période du projet, les mesures ayant démarré sur ces trois sites au cours de la période préliminaire à AMMA (voir ci-dessus). Ces trois domaines, qui couvrent chacun une surface comprise entre 10000 km² et 25000 km², sont les sites privilégiés pour les études de : couplage entre dynamique de la végétation et cycle de l'eau, occupation des terres (dynamique de la végétation) et érosion éolienne (Niamey), rétro-actions continent-atmosphère, transférabilité des modèles, fermeture des bilans et également pour l'étude des facteurs d'échelle dans le cycle hydrologique. Les mesures reproduites régulièrement ou de façon continue pendant l'EOP sur ces sites de mésoéchelle permettront en outre d'évaluer les variabilités spatiale et saisonnière des mécanismes privilégiés de transport, d'émission et de dépôt des aérosols et des composés gazeux.

Ces sites de méso-échelle abritent des super-sites et des sites intensifs locaux. D'autres bassins sont suivis, mais de manière moins intensive, par nos partenaires européens : bassin de la Volta (projet *GLOWA-Volta*) et bassin du Sénégal (projet *INTEA*). Ils serviront de support pour des études de transposabilité pour les modèles hydrologiques et pour densifier localement l'échantillonnage des

différents champs (pluviométrie, écoulements, recharge, dynamique de la végétation) fournis par les réseaux opérationnels.
Les caractéristiques des trois sites de méso-échelle sont données dans le tableau ***3*** en annexe.

Les super-sites et les sites intensifs locaux

Ces sites serviront de base à l'étude des processus de petite échelle : gradients pluviométriques liés à la convection, infiltration de l'eau du sol, recharge des nappes, couplage entre végétation et cycle de l'eau. Une liste des super-sites est donnée dans le tableau ***4*** en annexe de la partie EOP-LOP.

4.2.0.cNature des instruments mis en œuvre

Définition des instruments et plate-formes

Un instrument est un capteur ou un ensemble de capteurs dont les mesures permettent de réaliser un échantillonnage spatio-temporel cohérent d'une variable géophysique ou d'un ensemble de variables liées entre elles pour l'étude d'un processus donné. Différents facteurs techniques ou opérationnels (contraintes de mise en œuvre, colocalisation ou, inversement, dispersion géographique) peuvent amener à regrouper plusieurs capteurs en un seul instrument ou, au contraire, à "éclater" des ensembles cohérents de capteurs en plusieurs instruments. La définition des instruments, qui se traduit par la rédaction d'une fiche d'instruments est une étape importante pour la gestion de l'implémentation et pour la constitution de la base de données.
Les plate-formes font référence au support sur lequel sont implantés les instruments : avions, bateaux, sites terrestres (fenêtre sous régionale, site de méso-échelle, super-site).

Classes d'instruments

- ***Instrument isolé effectuant des mesures ponctuelles*** (ex : station météorologique).
- ***Réseau de stations*** réalisant un échantillonnage spatio-temporel cohérent sur un super-site ou un site de méso-échelle (typiquement un réseau de pluviographes, de sites de mesure de l'humidité des sols, de mesures du PAR), voire sur une fenêtre sous-régionale (réseau Photons, réseau GPS, réseau de bouées).
- ***Instrument isolé réalisant des mesures spatialement intégrées*** et/ou à grande couverture spatiale (typiquement un radar).
- ***Ensemble d'instruments colocalisés*** (étude locale des flux hydriques, instrumentation avion).
- ***Campagne de type cartographique*** (végétation, géophysique), *uniques ou répétées dans le temps.*
- ***Autres mesures*** (géochimie).
- ***Campagnes océanographiques*** (mesures avec un échantillonnage spatial optimal sur une région élargie mais une période limitée, mais répétées dans le temps)

Codification

Codification utilisée pour coder les instruments : ***Période.TypeMesure_NomPlateform***.
Période : L *pour LOP*, ***E*** *pour EOP*, ***S*** *pour SOP*
TypeMesure: à définir au cas par cas (ex : RS *pour radio-sondage*, ***Rain*** *pour pluie*, *, etc...).*
NomPlateform: voir liste des plate forme (ex : ST *pour transect sahélien*, ***Q1*** *pour quadrilatère EOP vapeur d'eau*, ***N*** *pour site Méso-Echelle Niamey*, ***O*** *pour site Méso-Echelle Ouémé, etc...).*
Exemples : **AE.RS_Q1 =** *Ensemble des cinq radio-sondages(**RS**) du quadrilatère bilan d'eau(**Q1**) fonctionnant pendant l'EOP(**E**).*

4.2.1 SOP Aircrafts

This Workpackage will insure that the airborne instrumentation necessary for achieving SOP scientific objectives (see 4.2.0.a above) will be installed and tested before the field phase, that the airborne experiments will be correctly conducted during the SOP, and that the airborne data will be quality checked and delivered to the project data base as far as available during the planning period. In cooperation with the demanding WPs (1.x, 2.x and 4.1.x) a set of experimental scenarios and coordinated flight plans will be worked out and summarized in the experimental plan for the field studies. The airborne instruments will be operated during the Special Observation Periods.

Description of work

Coordinated flights will be conducted with the British BAe-146 (UK / BAe), French ATR (FR / ATR) and Falcon (FR / F20), and German Falcon (DE / F20) aircraft (in addition to US / NOAA-P3, if definitively confirmed), in agreement with the flight capabilities, the onboard instrumentation, the scientific objectives and the weather situation, in order to sample key variables concerning the most important physical and chemical processes in the atmosphere of West-Africa as outlined in the targets of the process WPs. The list of observations is given in the *Aircraft AMMA instrumentation* table provided as an appendix. Three phases will occur :

- Preparation of the field phase concerning the scientific instruments and their installation in the aircraft, preparation of the "operation plan" including tight coordination between airborne and ground-based observations under WP 4.2 coordination. In cooperation with the related WPs a set of experimental scenarios will be worked out and summarized in the experimental plan for field studies. The main objective is to harmonize the experimental requirements from other WPs with the available aircraft, their capabilities and the associated instruments, and the ground-based operations.
- The field phase during SOP_0, 1 2 and 2b, during which resources must be rationally shared depending on the globally approved scientific priorities and on the weather conditions
- Data analysis and validation period, after which the data will be made available to all participants. The experimental data will be quality checked and delivered to the project data base as far as available during the planning period.

Deliverables

- Contribution to the Operation Plan &to the definition of the AMMA Operation Center
- Report on readiness of measurement systems
- Delivery of quality controlled data to the project data bank
- Documentation of progress on AMMA web site

Preliminary remarks

Two groups of scientists, mostly concerned in the “dynamical” or “chemical” aspects, have been involved in the preparation of aircraft operation during AMMA SOPs. This does not mean that no coordination exists between them, but it was first (e.g. in 2004) necessary to precisely define the scientific objectives and the sampling strategies for each domain before trying to elaborate common plans to maximize information on observed phenomena and to minimize the cost in terms of flight hours (e.g. 2005). Likewise, for each scientific objective, it will be necessary to more precisely link the French, German, British and (if confirmed) US aircraft flight plans to make the best use of the available means. However, some elements concerning national and international cooperation can already be found in the proposals. In addition, aircraft strategy has been designed having in mind the basic ground based network (many PIs are involved in both aircraft and ground based SOP field.

4.2.1.1. AEROSOL AND CHEMISTRY

Coordinator : P. Formenti
Participants: CNRM, LA, LAMP, LISA, LOA, IPSL, LSCE, SA, ELICO, Université Paris12 (UP12).

4.2.1.1.a 5-year work plan

I) General objectives

They are related to the WP2.4 (Aerosol and Chemistry Processes in the Atmosphere), in particular to the subWP2.4.1 “Aerosol radiative properties and hygroscopicity”, subWP2.4.2 “Gas and particle phase chemistry”, subWP2.4.3 “Surface processes”, and subWP2.4.4 “Effect of convection on chemical and aerosol budgets”. The objectives are also related to 1.1.2 which aims to quantify the impact of West African emissions on global trace gas/aerosol budgets, the oxidant capacity and radiative forcing and to WP 2.1 who looks at the aerosol impact on monsoon particularly through the heat low and the SAL.

The various sub-actions contributing to this WP are listed in the following Table, and identified by an acronym.

Acronym	PI	Laboratories	Main scientific objective
HYGRO	L. Gomes	CNRM/LAMP/LSCE/LA/ELICO	Hygroscopic properties of organic/inorganic aerosols
AVIRAD	P. Formenti	LISA/LSCE/UP12	Emission and optical properties of dust aerosols (w/o mixing)
LAUVA	P. Chazette / F. Dulac	LSCE	Optical properties of dust/biomass aerosols
CVI	A. Schwarzemboek	LAMP	Cloud optical and physical-chemical properties
PLASMA	D. Tanré	LOA	Radiative properties of dust/biomass aerosols
LEANDRE	J. Pelon	IPSL	Radiative properties of dust/biomass aerosols
MONA_SAMU	P. Perros / A. Kukuy / G. Ancellet	LISA / SA	Oxidant budget and transport/evolution of chemical tracers

II) SOP0 field phase

The AMMA SOP 0 (in previous documents also MAMA, Multi-observations of the Aerosol Mixing in Africa) is devoted to the study of the mixing between dust and biomass burning aerosols with various objectives: SOP-0 "Dry Season and aerosols" January-February 2006 to characterise dust and biomass burning aerosol properties (physical-chemical, hygroscopic and optical properties) and their variability over dust production areas and in the vicinity of fires. With respect to these objectives, a new request to API2005 is made to characterize all form of stratiform clouds in the WAM region by performing in-cloud measurements (see CVI proposal below).
Ground-based, airborne and satellite observations will be conducted in the area between 0–13°N, 3° E–20°W. In wintertime, dust and biomass aerosols are emitted from different areas (Sahara for dust and Sahel for biomass) and transported by the prevailing easterly winds towards the gulf of Guinea, where they get mixed mix. The persistence of clear-skies and absence of precipitations enhances their residence time, therefore their optical depth, e.g., their radiative forcing. In Figure 4.1.1.1, a POLDER image illustrates the extension of the area where the aerosol content is elevated.

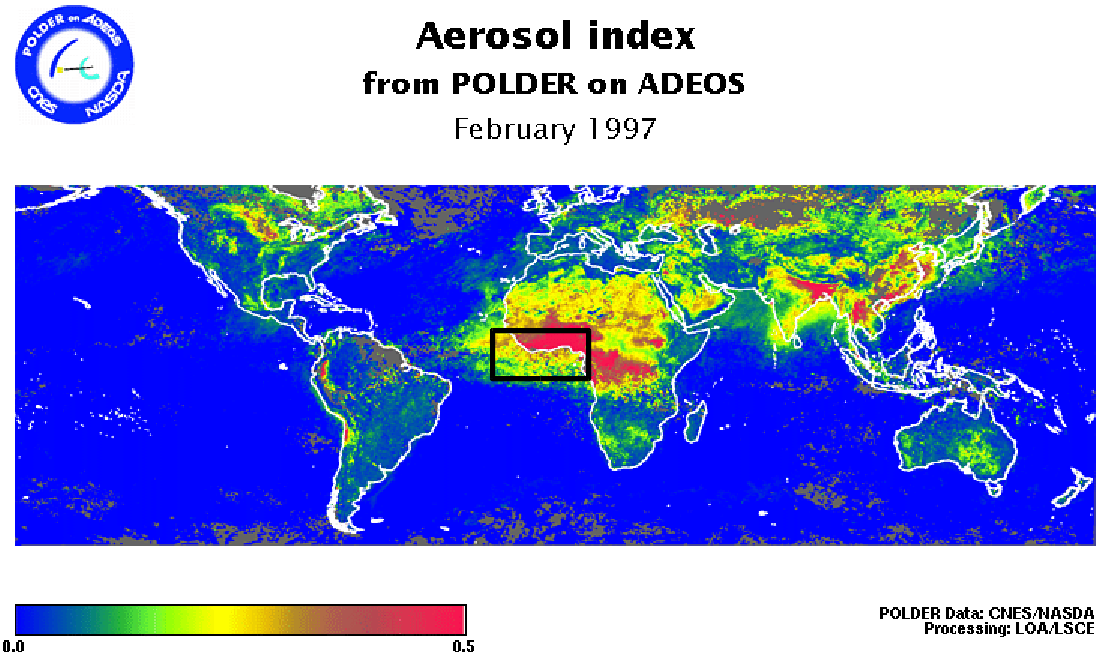


Figure 4.1.1.1. SOP0 investigating area (black square) superimposed to a POLDER retrieval of the aerosol index.

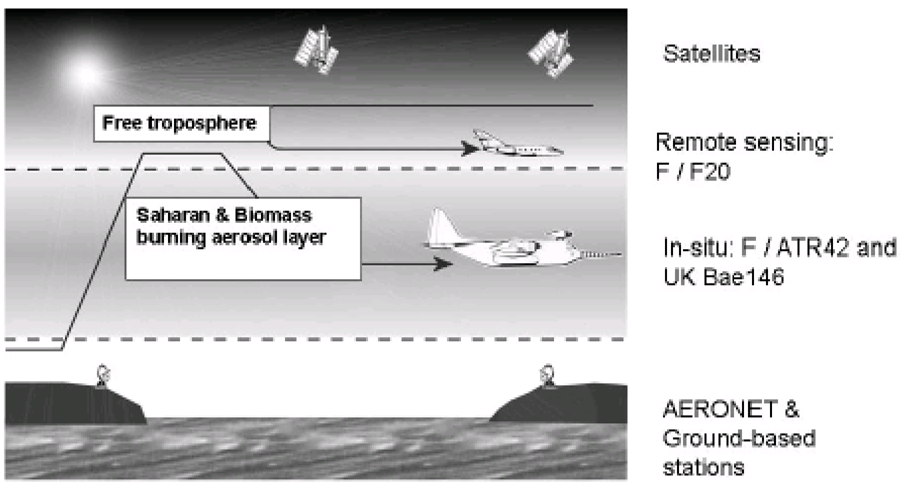


Figure 4.1.1.2. Schematics of the synergy between ground-based, airborne, and satellite platforms to sample and characterise dust and biomass aerosols during SOP0.

The experimental strategy to sample and characterise this mixing is schematised in Figure 4.1.1.2. Three main ground-based sites, all coinciding with AERONET stations, Banizoumbou (Niger), M'Bour (Senegal), and Djougou (Benin), will be equipped with in situ characterisation (physico-chemical and optical) instrumentations (see WP4.2.2 proposal).
The airborne in situ characterisation will be carried on using the FR / ATR. To constrain the optical properties of dust aerosols as a function of their mixing, the in situ size-resolved mass concentration and composition, number size distribution, and spectral optical properties (scattering/absorption) of mineral dust aerosols as a function of mixing will be measured from a number of instruments connected to a specific inlet able to sample coarse particles (see AVIRAD proposal; instruments

S.GRIMM_ATR42; S.AETH_ATR42; S. NEPH_ATR42; S.FILT_ATR42; S.DKT_ATR42 in Table 1).
Complementary optical measurements will be the aerosol backscatter coefficient profile measured at 355 nm by an onboard lidar (see LAUVA proposal; instrument S.LAUVA_ATR42 in Table 1) and the vertically–resolved spectral aerosol optical depth measured by the PLASMA sun-tracking photometer (instrument S.PLASMA_ATR42), as well as wing-mounted optical probes for measuring the number size distribution.
In addition, the aircraft will be equipped with an isokinetic particle inlet, adapted to PM2.5 aerosol fraction, which will be dedicated to measuring the number size distribution of CN and CCN, and studying the hygroscopic properties of organic aerosols, as a function of the mixing with inorganic species, and their links to the physico-chemical properties (see HYGRO proposal; instruments S.CPC_ATR42 + S.CCN_ATR42 + S.DMA_ATR42 + S.PCASP_ATR42 + S.THERMO_ATR42 + S.FIL_ATR42 in Table 1).
In-cloud measurements are proposed using an instrumental set coupled to a CVI inlet (see CVI proposal; instruments S.CVI_DMPS_ATR-42, S.CVI_LAS_ATR-42, S.CVI_HYGR_ATR-42, S.CVI_SPAR_ATR-42, S.CVI_CHEM_ATR-42, S.CVI_PSAP_ATR-42) providing with the direct measurement of CWC (IWC, LWC), cloud particle number concentration (equal to residual particle number concentration), measurement of the quantity of absorbing material in the cloud particles, chemistry and mass concentration of aerosol particle material dissolved in the cloud.
These in situ measurements will be coupled to the remote sensing observations onboard the F / F20, which will carry various radiometers and satellite simulators (DIRAC, CLIMAT, POLDER) and the two-wavelength Lidar LEANDRE NG. The F2O will also drop sondes to look at the atmosphere structure (about 1 dropsonde per flight).
The FR / ATR42 and FR / F20 dataset would provide with the opportunity of performing (a) internal consistency checks (signal-to-signal comparisons; examples: comparison of lidar signal by LAUVA and LEANDRE NG; comparison of number size distributions measured by inlet- and wing-mounted probes); (b) closure tests (examples: comparison of measured scattering/absorption coefficients to those calculated from measured physical-chemical properties; comparison of measured CCN/CN ratios to those expected from measured physical-chemical properties); (c) radiative calculations (example: calculation of measured radiative fields based on measured physical-chemical characteristics; this includes radiative fields measured by satellite); (d) remote-sensing product validation (examples: signal-to-signal validation, through the airborne simulators onboard the FR / F20; retrieval of micro-physical parameters combining in situ and remote sensing observations).
Based on Niamey, flights will be conducted on east–west transects to look at dust properties as well as transport, and north–south/southwest transects to look at the gradient of the aerosol properties resulting from the mixing between dust and carbonaceous aerosols. A typical aerosol-dedicated sortie of the FR / ATR includes at least one vertical profile to determine the vertical structure, and three-to-four straight level runs of variable horizontal span (duration ≥ 30 min) to allow for in situ sampling, as shown in Figure 3.
In Figure 4.1.1.3, one could note the triangular path for straight level run measurements. This is suggested in order to reduce the horizontal span whilst flying (and sampling!) at a constant level above a ground-based station, so to optimise the representativity of the airborne measurements with to those ground-based, whenever this complementarity is important. As an example, this flight plans are requested for aerosol filter sampling and determination of the absorption properties, which, in conjunction to faster measurements (size distribution, particle scattering) determined during profiles, can be used to study column closure with ground-based aerosol optical depth by AERONET.

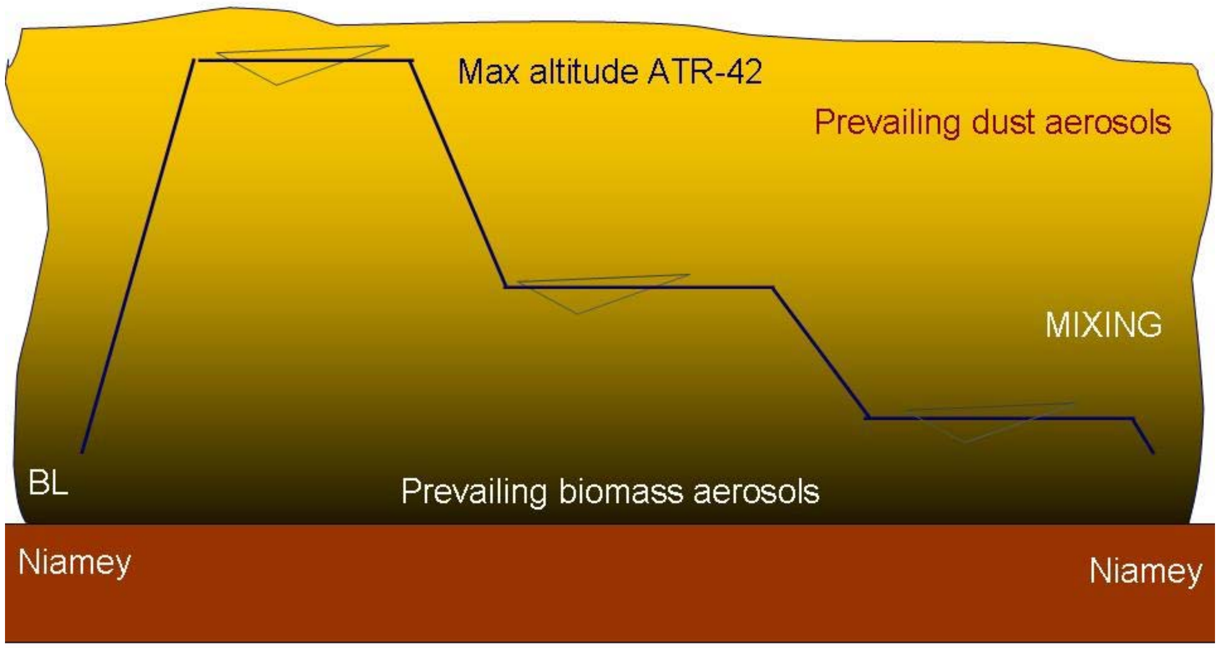


Figure 4.1.1.3. Proposed flight pattern for in situ aerosol sampling on the ATR42 during SOP0.

The FR / F20 during SOP0 should fly above the aerosol layer to ensure regional coverage of the aerosol distribution and optical properties, but also within and below for satellite-validation purposes. Coordinated flights (or at least portions of flights) between the FR / ATR42 and FR / F20 will be organised to optimise the synergy of the in situ and remote sensing approaches.

Furthermore, coordination with the UK BAe146 aircraft (PI: Jim Haywood) is being implemented. The BAe146, which likely will be based in Niamey, will perform in situ sampling and radiation measurements, in various flight configurations, spanning the vertical from 50 to 35000 feet.

The requested flight hours for SOP0 are summarised in Table 2.

SOP	*EXPERIMENT (PI)*	*REMARK*	*AIRCRAFT*	*nb of IOPs*	*FLIGHT HOURS*
0	**SOP-0.F20** Remote sensing aerosol (PI : D. Tanré)	to be coordinated with UK / Bae-146	FR / F-20	9	**40.5 h**
0	**SOP-0.ATR** In situ aerosol (PI : D. Tanré)	to be coordinated with UK /Bae-146	FR / ATR-42	11 $$	**60.5 h**
$$ With respect to API2004, two additional flights are requested to the API2005 for in-cloud investigation (see CVI proposal, Schwarzenboeck et al.).					

III) SOPs 1–2–3

In the wet monsoon season, aerosols and gases are emitted from the Sahelian region through erosion of disturbed soils by squall lines (dust aerosols) and by the vegetation (organic aerosols and gaseous oxygenated compounds). These components are transported westward and uplifted by the large convective systems, as well as being modified in the interaction. The wet season field campaign has been declined into three scientific phases corresponding to three differing scientific objectives:

- SOP-1 "Monsoon Onset" May-July 2006 and SOP-2 "Monsoon Maximum" July-August 2006 to investigate aerosol and gas emissions, and their uplift, horizontal transport, and modification by convective systems. Of particular interest are: (a) dust emissions, and their microphysical/optical properties, due to the passage of squall lines over the disturbed Sahel; (b) organic aerosols from biogenic/anthropogenic precursors; (c) major gaseous oxidants.
- SOP-3 “Late Monsoon” August-September 2006 to study the regional scale impact of the WAM on chemical/aerosol evolution downwind from convective systems. The long-range transport of WAM pollutants out of West Africa will also be investigated. Note that it is now envisaged that SOP3 will have a shorter duration of 2-3 weeks and will take place at the end of SOP2 in order to have coordinated flights between the French/UK aircraft based at Niamey and the DD/F20 which is likely to be based in Dakar.

In situ aerosol measurements will be dedicated to the estimation of the emissions and physical/chemical/optical properties of mineral dust (AVIRAD proposal; instruments S.GRIMM_ATR42; S.AETH_ATR42; S. NEPH_ATR42; S.FILT_ATR42; S.DKT_ATR42) and to the characterisation of the CCN capacity of organic/inorganic aerosols with link to their intrinsic properties (see HYGRO proposal; instruments S.CPC_ATR42 + S.CCN_ATR42 + S.DMA_ATR42 + S.PCASP_ATR42 + S.THERMO_ATR42 + S.FIL_ATR42). These will be performed during SOP1–2. In-cloud measurements are additionally requested to characterise various properties of the hydrometeor residual as well as interstitial aerosols with link to the aerosol indirect radiative effects (see CVI proposal; instruments S.CVI_DMPS_ATR-42, S.CVI_LAS_ATR-42, S.CVI_HYGR_ATR-42, S.CVI_SPAR_ATR-42, S.CVI_CHEM_ATR-42, S.CVI_PSAP_ATR-42). Gas phase measurements of ozone, reactive nitrogen species (NOx, NOy, HNO_3, PAN), carbon monoxide, hydro- and organic peroxides, VOCs (C4–C10, aldehydes, ketones, di-carbonyl and hydroxy-carbonyl compounds), CO, RO_2 radicals, OH and HO_2 will be performed during SOP 2 and 3 using both the FR / ATR and the FR / F20 platforms, with the objective of (a) defining the budget of peroxy-radical in the upper troposphere; (b) establishing the regional export of chemical species with a focus on the end of the monsoon period (SOP-3); and (c) studying the chemical evolution of air masses in order to evaluate the convective system impact at synoptic scale in the lower troposphere. Measurements will be made in situ, either via on line instrumentation and collection and post-flight sample analysis (see MONA_SAMU proposal; instruments S.HOX_FF20, S.Mona_FF20, S.COV_FF20, S.COVO_FF20, S.MOZART_FF20, S.COV_ATR42, S.COVO_ATR42, S.PEROX_ATR42, S.PAN_ATR42, S.NOx_ATR42). Three different set of scientific deliverables are evaluated in the MONA_SAMU proposal depending on the status of advancement of the SAMU instrument.

Similar to SOP 0, ground-based, airborne and satellite observations will be coordinated in the area between 0–13°N, 3°E–20°W. Overpasses of the main ground-based sites (Banizoumbou (Niger) and Djougou (Benin)), as well as of secondary stations (Lamto (Ivory Coast), Cinzana (Mali), M'Bour (Senegal) see WP4.2.2 proposal) is requested.

Dust emissions and properties will be characterised by in situ sampling before and after the passage of identified squall line systems during flights as above as possible the Banizoumbou ground-based station as well as over east–west transects at fixed latitude (see AVIRAD proposal). SOP 1 conditions (non-precipitating convective systems) are preferred for this task.

Organic/inorganic aerosols and gas sampling will be performed on the fore and the back head of a mesoscale convective system (MCS) on north–south transects along the Niamey-Parakou-Cotonou

axis during SOP 1 and SOP 2 as described in Figure 4. A typical aerosol-dedicated sortie will include at least two vertical profiles each side of the ITF to determine the vertical structure, and three-to-four straight level runs of variable horizontal span to allow for in situ sampling. Additional planetary boundary layer profiles (profile lengths: 100-300 km) perpendicular to the MCS propagation are requested to analyse smaller convective systems ahead and downstream (post-MCS stratiform clouds), the developing MCS (e.g. characterization of stratocumulus type cloud fields that may reach the Gulf of Guinea (see CVI proposal). Two groups of scientists, mostly involved in the dynamical and chemical aspects, are involved in the preparation of aircraft operation during AMMA SOPs. An important action has to be conducted in 2005 to more precisely coordinate the scientific objectives and experimental design for both aspects. However, from now, different types of flights already envisaged for studying the ABL conditions (see proposal made by F. Saïd, SOP-1.ATR.NS-DYNAMICS; SOP-1.F20.NS-DYNAMICS; SOP-2.ATR.DYN-BUDGET) fulfil the needs for chemistry measurements all along a north-south transect (CATCH window). These dynamical/chemical coordinated flights conducted on the FR-ATR will help to better understand the relationship between cloud dynamics and precipitation and the local evolution of atmospheric chemistry (gases and aerosols). The objectives of these flights are (1) to document the interactions between the south-westerly monsoon flow and the easterly Harmattan in the transition zone during the pre-onset and the onset of the monsoon; (2) to document the structure of the monsoon flow along the longest possible north-south transect (Niamey-Cotonou).
Complementarity of aircraft capabilities will allow sampling the column aerosol and gas content and properties. An example of coordination is shown in Figure 4.1.1.4, showing the FR / ATR42 sampling the lowest part of the troposphere at various altitudes along a north–south axis, and the UK / BAe146 and F / F20 documenting the chemical composition and the atmospheric structure in the middle troposphere and low stratosphere. During SOP1 the BAe should not be available; therefore coordination between chemical measurements will be carried on between French aircrafts only. Attempts will be made to coordinate flights (especially ATR) with surface flux measurements, ground-based aerosol lidar, trace gas measurements and ozone soundings.

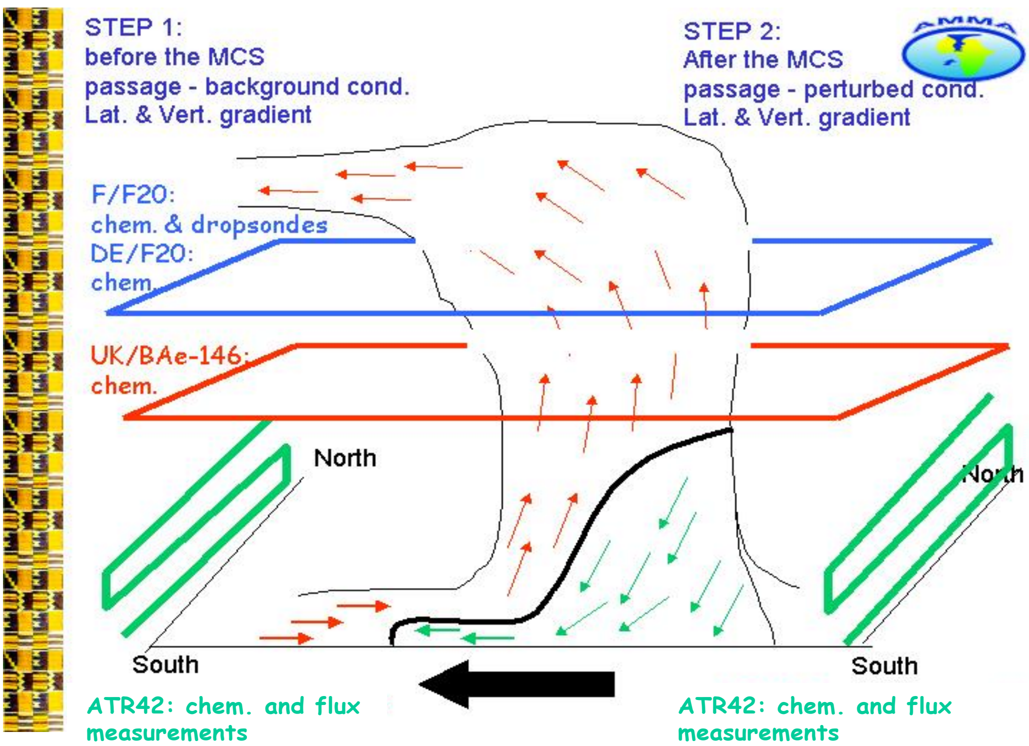


Figure 4.1.1.4. Investigation of aerosols and gases around MCS during SOPs 1–2.

During SOP3 it is proposed to have coordinated flights between the FR/F-20 and the UK B-146 based in Niamey and the DD/F-20 which is likely to be based in Dakar. The aim will be to characterise chemical and aerosol distributions and evolution in air masses advected downwind from convective systems and thus to collect data on a larger scale than proposed in SOP2 which focuses on the transport within and around MCS. Therefore, it is envisaged that the FR / F20 and/or the UK BAe-146 will make east-west transect flights to Dakar where the DD/F-20 will make flights into the advected air masses further downwind over the North Atlantic. Links with the balloon flights of SCOUT-AMMA will be pursued. A possible flying strategy is shown below.

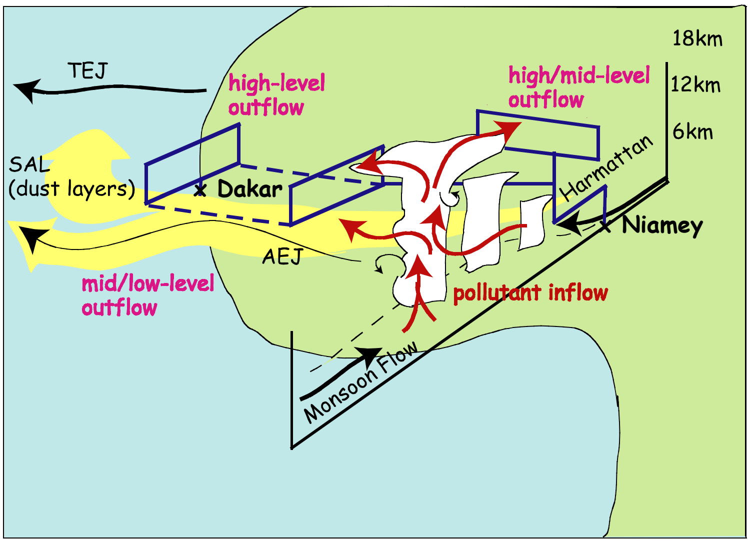


Figure 4.1.1.5. Flight strategy during SOP 3.

Flights may also take place in other locations identified as major outflow pathways for pollutants. Analysis of satellite data (in 1.1.2) will help to elucidate such pathways. Collection of balloon data on trace gas composition in the TTL will also be coordinated with these flights. Complementary trace gas, aerosol and radical measurements on the different aircraft will enable characterisation of transport pathways and photochemical/aerosol reactivity during transport. The data will be used in conjunction with other data sources such as satellite data and modelling (1.1.2) to quantify the impact of the WAM on the oxidising capacity, tropospheric ozone budget, aerosol formation and radiative forcing. The requested flight hours for SOP 1–2–3 are summarised in Table 2.

SOP	EXPERIMENT (PI)	REMARK	AIRCRAFT	nb of IOPs	FLIGHT HOURS
1 (2) $$$	**SOP-1(2).ATR. EW-AEROSOL** EW transect aerosol (PI : P. Formenti)	to be coordinated with Bae-146 and DE / F-20	FR / ATR-42	6	***33 h***
$$$ The study of dust emissions by squall lines should preferentially be performed during SOP1, when the convective systems are more frequently non-precipitating. However, these flights would be performed during SOP2 in difficulties would arise (e.g., no squall lines, aircraft problems, coordination, etc).					
1+2	**SOP-12.ATR. NS-AEROSOL** N-S / SW transect aerosol (PI : L. Gomes)	to be coordinated with Bae-146 and DE / F-20	FR / ATR-42	8 $$	***44 h***
$$ With respect to API2004, two additional flights are requested to the API2005 for in-cloud investigation (see CVI proposal, Schwarzenboeck et al.).					

SOP	EXPERIMENT (PI)	REMARK	AIRCRAFT	nb of IOPs	FLIGHT HOURS
2	**SOP-2.ATR. CHEM-BUDGET** Gas phase measurements & chemistry budget (PI : P. Perros)	to be coordinated with BAe-146 and DE / F-20	FR / ATR-42	8	***44 h***
2	**SOP-2.F20. CHEM-BUDGET** Gas phase measurements & chemistry budget (PI : G. Ancellet/ P. Perros)	to be coordinated with Bae-146 and DE / F-20	FR / F-20	8	***36 h***
2	**SOP-2.F20. CHEM-TRANSPORT** Chemistry transport over W Africa (PI : K. Law)	to be coordinated with BAe-146 and DE / F-20	FR / F-20	3	***13.5 h***

IV) Links of WP4.2.1 observations with satellite activities

As for WP4.2.2, the links between observations and satellite activities are mainly through the validation of spaceborne products, and through process studies for improvement of spaceborne retrieval methods.
WP4.2.1 will to provide a high-quality set of observations relevant for the calibration/validation of satellite-derived aerosol products over the Sahara/Sahel, and the specific validation of CALIPSO measurements (combined lidar and IR Radiometer measurements) over the Sahara. The backbone measurements will be provided by CALIOP and the IR radiometer from CALIPSO, PARASOL as well as radiation measurements (CERES). CALIOP validation aspect include level 1 products (e.g. signal to signal comparison) and level 2 products (e;g. extinction and backscattering profiles, geometrical and optical properties of aerosol layers).
The airborne aerosol characterization (size distribution, mineralogical composition, spectral diffusion and absorption properties…) coupled with measurements at ground level will also be used to constrain both ground-based and space remote sensing (Lidar…).
Satellite measurements of trace gases and aerosols will also be used to study pollutant transport pathways into and out of West Africa (i.e. MOPITT, SCIAMACHY, possibly IASI, MODIS, CALIPSO). Together with associated modeling and SOP3 (3) data analysis planned in WP1.1.2 this will allow quantification of the impact of West African emissions on the global budgets of aerosols and trace gases. It will also allow the aircraft data to be put into a wider context that is useful for global model evaluation and data analyses.

4.2.1.1.b Activities in 2004

Most of the activities in 2004 have been delayed as the aircrafts have not yet been delivered. Activities in 2004 have been mostly dedicated to instrument definition and preparation. Most of the instrumentation is under development at this stage of the proposal.

i) Aerosol instrumentation

As detailed previously, three aerosol operations with different objectives and specificity are proposed during AMMA:

- the HYGRO proposal, using the "community inlet" for PM2.5 particles and measuring size distribution, chemical composition, and CCN/CN ratios from a temperature-controlled line to look at the dependence of the CCN/CN ratio on size and surface properties;

- the AVIRAD proposal, using the AVIRAD for coarse particles, and measuring size distribution, individual particle size and morphology, size-segregated mineralogical composition and optical properties to look at mass emissions, characterisation and optical closure for dust aerosols;
- the CVI proposal, using a counterflow virtual impactor (CVI) inlet and measuring size distribution, chemical composition, individual particle morphology, absorption to look cloud and interstitial aerosol properties.

Except for the CVI, that was not present in the API2004 proposal, activities in 2004 for the "community inlet" and the AVIRAD have focused on the definition scientific objectives, of adequate flight plans, and to the definition/acquisition (or order) of the instrumentation. Current late 2004, the AVIRAD will be certified onboard the FR / ATR42. The "community inlet" and the CVI are under construction, and ought to be delivered in December 2004 and March 2005, respectively. The three operations are uncertain as the respective inlets have to be located in the forefront part of the aircraft. The instrumented racks behind the respective aerosol inlets are competing for aircraft space, and their co-location is likely to block the corridor for access. The solution to this technical point is under investigation in collaboration with SAFIRE. Furthermore, it has been recently decided that a test flight to determine experimentally the passing efficiency of the "community inlet" and the AVIRAD will be performed current 2005. Depending on these tests, and the technical feasibility of the implantation, some of the scientific objectives of IP and API AMMA could not be achieved.

ii) Gas phase instrumentation

A risk exists regarding the readiness of SAMU, due to technical problems on the gas inlet. Some difficulties exist as well on the simultaneous implantation of SAMU and MONA onboard the F / F20. Three different set of scientific deliverables have been defined according to the state and availability of SAMU (see SAMU_MONA proposal). The current working hypothesis (for which costs have been estimated) is that the has inlet fr SAMU will not be available and HO_2, RO_2, but not OH will be measured.

iii) Coordination

Most of the coordination effort has been made within the boundaries of the French community. Various meetings have been organised current 2004. The airborne sampling strategy has been decided as a complement to the ground-based payload. Still, closer coordination is needed in defining the aerosol sampling strategy and in defining common flight plans amongst aircrafts (in particular UK BAe146, DLR F20, etc).

<u>Publications and work rapports</u>

Rojas S., P. Laj, P. Villani, D. Orsini and L. Gomes, Propriétés hygroscopiques des aérosols : rôle des états de surface, Atelier Expérimentation et Instrumentation, Paris, 23-24 mars, 2004.
Villani P., P. Laj, D. Picard and L. Gomes, A new H-TDMA instrument: setup and arrangement, Atelier Expérimentation et Instrumentation, Paris, 23-24 mars, 2004.
Formenti et al., Intégration d'AVIRAD sur l'ATR-42, demande de soutien technique à la DT-INSU, 17 octobre 2003.

4.2.1.1.c 2005 Plan

Plan for AVIRAD: Study of the emissions and properties of mineral dust aerosols from the Sahelian region by aircraft sampling: description of the instrumental payload (AVIRAD inlet + instrumented rack) and proposed flight plans
Coord: P. Formenti
Laboratoire : LISA

i) Scientific objectives

With links to WP 1.1., 2.1 and 2.4

- To determine the physico-chemical and optical properties of mineral dust aerosols as a function of source region (Sahara/Sahel), mixing with biomass burning, and modification due to cloud interactions.
- To assess the variability of aerosol emissions over WA due to wind erosion.
- To evaluate the role of the MCSs in the transport of aerosols from WA to the global scales

ii) Description of the work

In order to investigate emissions of mineral dust aerosols and quantify their radiative forcing, during SOPs the mass concentrations and the physico-chemical and optical properties of mineral dust will be measured during dedicated flights of the French ATR-42 aircraft.
The airborne measurements will provide the size-resolved mass concentration and chemical composition, number size distribution, and spectrally resolved optical properties (scattering/absorption) as a function of altitude from a number of instruments connected to specific inlet, the AVIRAD, able to sample coarse aerosols. This experimental strategy should reduce the uncertainties due to sampling from inlets with different efficiencies. This has a twofold necessity: (1) linking size-resolved mass and number particle distributions is needed to estimate the radiative impact of dust aerosols (which depends on number distribution) to emissions (which depends on mass) (2) to perform closure studies between the physical-chemical and optical properties, which, in the case of mineral dust aerosols, are not related by simple analytical relationships, but vary in a complex way based on the individual particle shape and degree of mixing.

Number of requested flight hours
We will participate to the clear-sky flights of the SOP0 (9 flights currently requested to the API-AMMA). We request 6 coupled flights (33 flight hours) during SOP1 to investigate the mineral dust emissions due to squall line events. Flying during SOP1 is preferred because at the beginning of the monsoon season convective systems are generally non-precipitating. The occurrence of precipitation (removing aerosols) becomes higher at the monsoon maximum, therefore flying during SOP2 is considered possible but not ideal to achieve our scientific objectives.

Description of flight plans (include scheme)
SOP0

During SOP0, aerosol mixing is supposed to show a latitudinal gradient between Niamey, the aircraft base, where mineral dust aerosols dominate, and the Gulf of Guinea, where aerosols from biomass burning prevail. To look at this gradient, flights will be conducted between Niamey and Cotounou, where two of the AMMA ground-based super-sites are located. A further southward excursion above sea would allow for coordination with satellite overpasses, to serve for validation purposes. This excursion is likely to be possible only during a double flight with technical scale and refuel in Cotounou.

To look at dust export towards the Atlantic, flights will be conducted at the latitude of Niamey (13° N) as east-west excursions towards the Lake Chad (one of the major dust sources at the global scale) on the east, and towards Mali on the west, as far as the maximum F / ATR42 flight endurance and as sampling requirements allow. Overpass of the two secondary AMMA ground-based sites, Zanderij, equipped with column remote detection equipment, and Cinzana (Mali), equipped with column remote sensing and surface in situ concentration measurements, is envisaged. Depending of aircraft hour availability, fly-by of the M'Bour ground-based station is also envisaged (this would request landing and refuel).
As illustrated in Figure, a typical flight plan would include at least one vertical profile between the minimum and the maximum altitude of the F / ATR42 to look at the aerosol vertical distribution, and a series of straight level runs within the aerosol layer to sample the chemical composition and mass distribution and, in general, to study their properties. Based on conservative figures of expected aerosol concentrations, and the minimum detection limits of the selected analytical techniques, we foresee 30 minutes as a largely sufficient duration for sample exposure, and therefore as an upper limit for the duration of the straight level runs. In order to reduce the horizontal spanned area, so to optimise the comparison with measurements performed at ground-based sites, straight level runs could be performed in a closed geometry (see Figure 1). Triangular are preferred to square patterns because of the lesser number of turns during which the aerosol sampling is not possible because affected by aircraft banking.

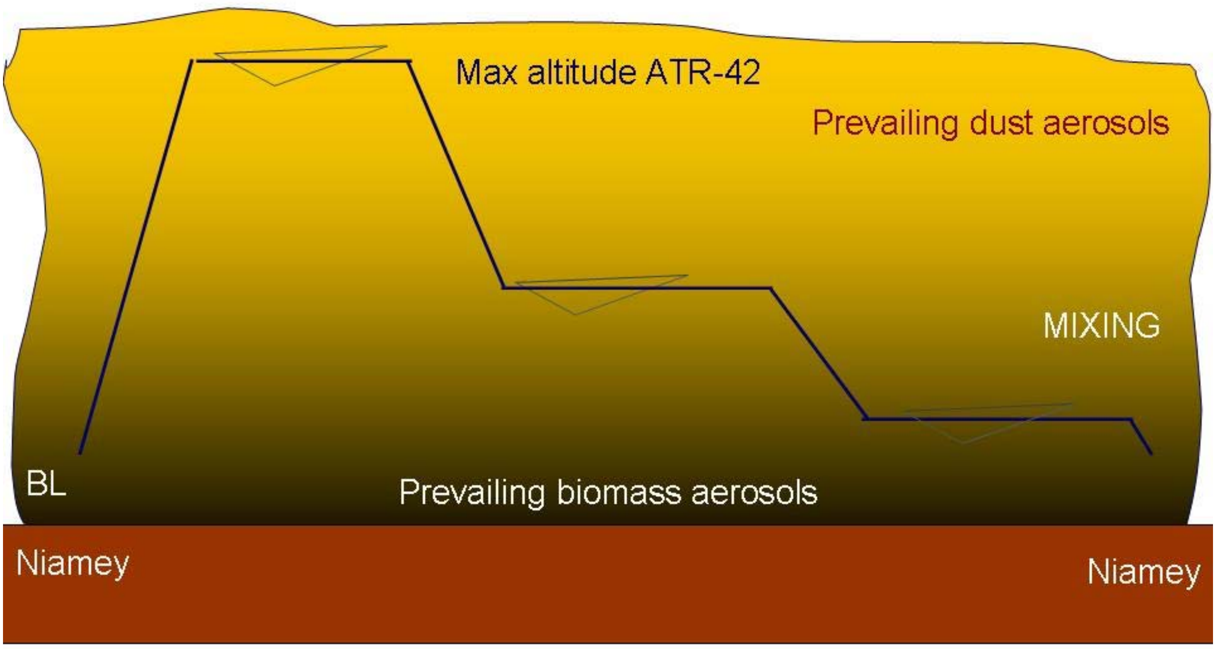


Figure . Proposed flight pattern during SOP0.

SOP1 (2)

In the wet season, dust emissions in the Sahelian region occur from erosion of disturbed soils by squall line events travelling westwards towards the Atlantic. Squall lines are large convective systems, often followed by heavy rains. Meso-scale modelling (*G. Cautenet*, personnel communication, 2004) indicates that dust advected by squall lines can reach up to several km in altitude, the highest concentrations being found below 5 km agl, where it can feed the Saharan Air Layer (SAL), a dust-laden layer transported westward towards the Atlantic by the easterly Harmattan flow. If not removed by rains, dust concentrations transported within the SAL should therefore be higher in correspondence of a squall line passage. As a matter of fact, simultaneous surface and column measurements above the Atlantic suggest that in the transport region, column extinction is highest during the monsoon season, and that is due to dust advected above the surface layer. The question is therefore to determine whether local emissions due to squall lines feed the SAL transported from Northern Africa to the Atlantic.

To do so, we propose to fly two coupled flights, one before and one after the passage of a squall line, and compare dust concentrations as a function of attitude before and after the event. Similarly to SOP 0, a typical flight path (Figure 2) should include at least one vertical profile between the minimum and the maximum vertical range of the F / ATR42, and a series of three-to-four straight level runs at various altitudes for aerosol sampling. In addition, the post squall-line event flight should include an eastward excursion to quantify dust concentration remaining in suspension in the atmosphere as a consequence of the passage of the squall line.

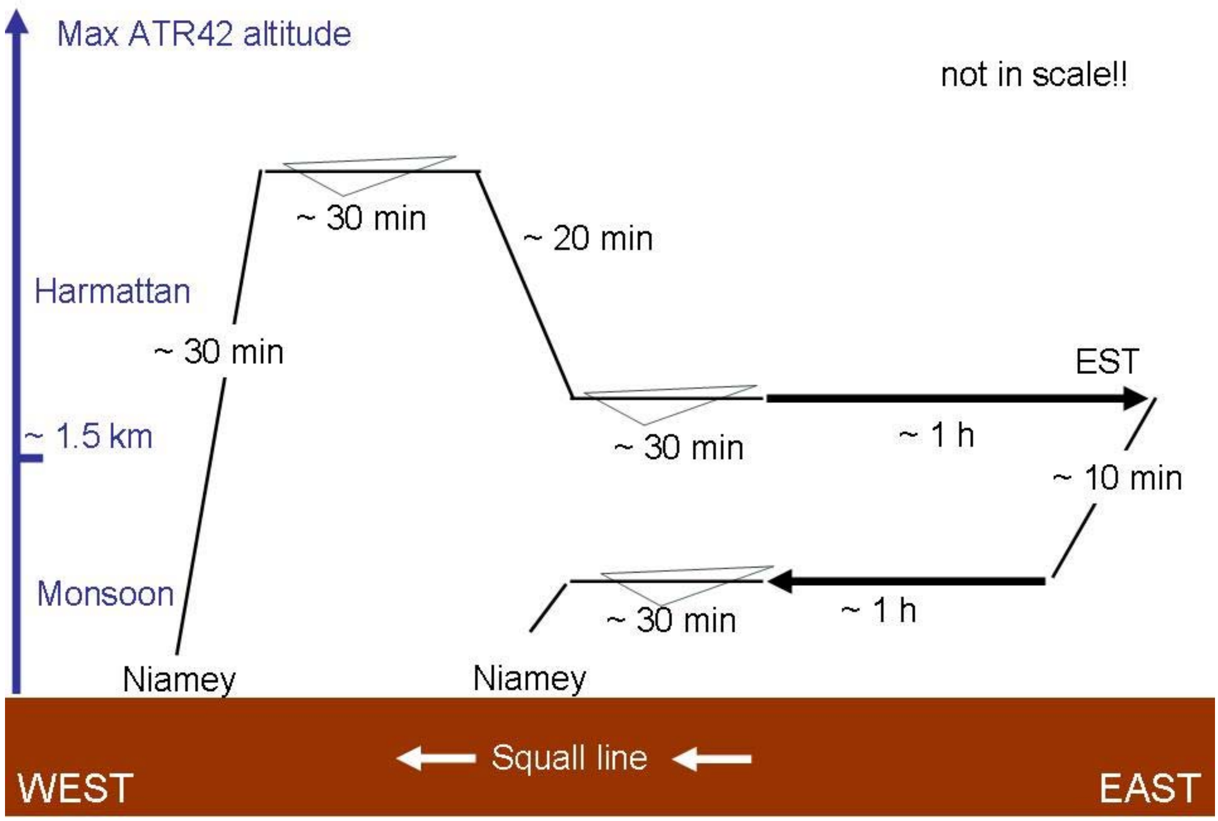


Figure 2. Proposed flight plan during SOP 1 (2).

To have sufficient statistical representation, we propose to document at least three squall line events, e.g., we request 6 coupled pre-and-post squall line passage flights. Flights should be preferentially flown during SOP1, when squall lines are not precipitating, thus the dust content in the atmosphere is highest, and the logistical constraints of operating the aircrafts are lower. In the absence of suitable events, flights will be flown during SOP2.

Complementarity with other airborne instrumentation (same aircraft) / Coordination with other aircraft platforms (french and/or international) / Coordination with ground-based stations

The AVIRAD instrumental payload will provide aerosol number, mass concentrations, chemical composition and particle shape as a function of particle size, and aerosol scattering and absorption as a function of wavelength. Coordination with the aerosol measurements from the "community inlet" (see L. Gomes proposal), in particular regarding filter sampling, is necessary in order to optimise operation. During SOP 0, the proposed operations are complementary to the vertical profiles of the aerosol backscatter coefficient provided by the LAUVA lidar, and to the vertical profiles of spectral optical depth measured by the PLASMA airborne sun photometer, by providing the micro-physical parameters needed to retrieve or to validate the remote sensing retrievals. Flying the LAUVA lidar onboard the F / ATR42, or fly-bys of the F / F20 carrying onboard LEANDRE-NG would give illustration of the aerosol vertical structure, helping the mission scientist in the determination of the vertical layers to be sampled.

Coordination with the UK BAe146 measurements is under progress. During SOP 0, the UK BAe146 will be equipped with aerosol and radiation measurements, allowing for the micro-physical and the remote sensing determination of aerosol properties. During SOP 2, the aircraft payload will be more dedicated to gas phase measurements, still carrying onboard an aerosol mass spectrometer (AMS) and a standard aerosol kit (nephelometer, PSAP, wing-mounted optical counters). During all SOPs, it is recommended that the aerosol measurements are carried as far as possible from the LTI inlet. Short-duration fly-bys (< 30 min) at various altitudes are requested for instrument comparison and measurement validation purposes.

During SOP2, coordination with the aerosol measurements onboard the DLR / F20 will allow to complete the information on the aerosol vertical distribution.

During SOP 0, this would be possible also by coordinating overpasses of the ground-based lidar (U. Munich) at the ground-based station of Banizoumbou. During SOP 1 (2), lidar overpasses are still uncertain, as, depending on IP-AMMA funding, the ground-based lidar profiles (ISAC/CNR) could be available at night-time only, when flying will not be allowed. In this case, profiles will be use for planning purposes only.

During all SOPs, profiling and fly-bys of the ground-based station of Banizoumbou is planned to link surface to column measurements. The enable comparison, the experimental strategy (sampling of multi-parameters from a well constrained air mass selected by a single aerosol inlet) onboard the aircraft has been modelled to that at the ground (see LISA proposal, Rajot, Desboeufs et al., WP4.2.2). The ground-based measurements at Banizoumbou will include the mass and number concentration and associated size distribution, the size-resolved chemical and mineralogical composition, a determination of the particle shape, and spectrally-resolved aerosol optical properties (scattering/absorption). Furthermore, in complement to aircraft measurements, during SOP 1–2, local dust flux measurements will be performed at Banizoumbou to determine experimentally the mass and number size-resolved emissions and deposition fluxes. These measurements will be used to validate the dust size dust emission model developed at the LISA, and especially its capability to predict the aerosols size-distribution as a function of wind conditions. The behaviour of dust during squall line events will be modelled using a meso-scale model (RAMS), initialised with the field flux measurements. These high-resolution simulations should allow establishing a parameterisation to be used for long-term simulations within a regional model.

Flying upon alert (minimum time)

From the instrumental point of view, one hour should be sufficient for two people to prepare the filters and impactors to be exposed during the flight.
From the scientific point of view, we plan to fly before and after a squall line event. Around 13°N, squall lines occur generally at night. We therefore would need an afternoon flight and a next morning flight. That means that in order to fly the previous afternoon flight without danger, we would need a morning warning of the approaching of the squall line (e.g., radar).

Logistic at the airport

At Niamey:
1) Clean laboratory space at the airport or proximity to prepare filter and impactor samples to be exposed during flights. A minimum 10 m^2 surface is requested to accommodate a portable bench at laminar flow.
2) Storage space (~ 5 m^2) for tools and boxes.
3) Easy access to the airport: access beyond airport opening times, if any.
4) Ground-power at least two hours prior and after the flight.
5) Availability of planning tools: internet/phone connection, met charts, satellite images, model cloud and aerosol predictions

At other airports
1) Ground-power at least two hours prior and after the flight.

iii) Deliverables

1) Operating and certified instrumentation (inlet AVIRAD + instrumented aerosol rack) for AMMA SOPs.
2) Contribution to planning coordination at French and international level (flight planning and coordination to ground-based stations)

iv)Milestones

October 2004: avionic certification of the AVIRAD inlet onboard the F / ATR42
January 2005–June 2005: setting up of the airborne instrumentation
June 2005: readiness of the AVIRAD inlet and airborne instrumentation
October 2005: test of the airborne system in Toulouse
February 2006: participation in the SOP0

Plan for HYGRO : Caractérisation des propriétés physico-chimiques, hygroscopiques et optiques du mélange d'aérosols

Laboratoires : CNRM, LAMP, LA, LSCE, ELICO
Coordination: L.t Gomes

i)Scientific objectives

Caractériser les propriétés physico-chimiques, hygroscopiques et optiques du mélange d'aérosols (dust, BC, organique (SOA) et biogénique) et leurs distributions régionales et verticales dans la région de mousson ouest-africaine afin de répondre aux objectifs scientifiques du programme AMMA, en particulier de son WP 2.4 (Aérosols/Chimie).

ii)Description of the work

Aerosol measurements will be performed during SOP 0, 1, 2. The in situ characterisation will be carried on using the F/ATR-42. This aircraft will be equipped with external instruments (PMS, X-Probe) and an isokinetic particle inlet, adapted to PM2.5 aerosol fraction, which will be dedicated to measuring the number size distribution of CN and CCN, and studying the hygroscopic and volatility properties of organic aerosols, as a function of the mixing with inorganic species, and their links to the physico-chemical properties.

Aircraft :FR-ATR-42:
Number of requested flight hours:
SOP 0:45 heures (9 vols) partagées avec groupes aérosol/dust, chimie/gaz et dynamique dont 20 heures (4 vols) en transect nord-sud
SOP 1 + 2:30 heures (6 vols) dédiées au transect nord-sud

Description of flight plans: (see API-2004 proposal):
Flights will be mainly conducted during clear sky or during combined flights (cloudless aerosol with in-cloud particle characterization) at low level on north–south/southwest transects to look at the N-S spatial variability and the regional gradient of the aerosol properties, in particular hygroscopicity, resulting from the mixing between dust and carbonaceous aerosols. A typical aerosol-dedicated sortie of the F/ATR-42 will follow a Niamey-Parakou-Cotonou axis during SOP 1-2 or a Niamey-Abidjan axis during SOP 0 and will include at least two vertical profiles each side of the ITF to determine the vertical structure, and three-to-four straight level runs of variable horizontal span to allow for in situ sampling. The N-S transect can be extended from 20°N to study the heat low to 2° N to study the impact of the sea surface fluxes in the Guinean Gulf.

Complementarity with other airborne instrumentation (same aircraft) :
Propriétés physico-chimiques des aérosols résiduels et intersticiels prélevés dans les nuages en SOP 0 (veine CVI, A. Schwarzenboeck, LAMP) ; Propriétés optiques des aérosols SOP 0-2 (Formenti, LISA) ; Chimie gaz (NOx, CO, O3, VOC) SOP 2 (Perros, LISA) et dynamique (émissions et dépôts) SOP 1-2 (Saïd, LA).

Coordination with other aircraft platforms (french and/or international):
coordinations with the UK BAe-146 (aerosol and chemistry, mid-level flights, altitude range 6–9 km, SOP0) and the D/F20 (aerosol and chemistry, high level flights, altitude range 9-12 km, SOP2).

Coordination with ground-based stations :
Coordination with aerosol stations (Banizoubou, Niger; Djougou, Benin; Lamto, Ivory Coast), and IDAF and AERONET network stations

Flying upon alert (minimum time): Vols sur alerte déclenchée par NAAPS NRL model (dust) et MODIS (biomass). Minimum time 30 min.

Logistics at the airport: 1 pièce de stockage à l'aéroport

Deliverables 2004:

- Com inlet is under construction and will be delivered in december 2004.
- Most of missing equipment has been purchased or ordered.
- Installation of airborne instrumentation has been postponed to 2005 since the aircraft is not yet available.
- Coordination with other ground based sites of the N-S transect has been discussed in order to get ground-based reference measurements.

Deliverables 2005:

During 2005 the com inlet will be equipped with the data acquisition system including software to control the isokinetic inlet, flow controllers, pressure and temperature sensors. The integration of the measurement systems will be finalised in June 2005 for certification including test flights onboard the aircraft ATR-42 planned within the second semester of 2005. The performance of the Com inlet and its instruments will be checked during these flights.
Beside standard instrumentation (CPC, OPC, CCNC), the instrumentation system will include a thermodenuder upstream the DMPS and various kinds of filters for chemical bulk (inorganic/organic material).

Milestones

T0 (= 1/1/2005) reception of Com Inlet
T0+1: installation/adaptation on ATR-42
T0+06: instruments installed; planning of the aircraft operation
T0+07: starting of test flights
T0+11: equipment successfully installed and tested
T0+13: participation to SOP 0 (measurements and aircraft operations)
T0+18: participation to SOP 1 (measurements and aircraft operations)
T0+19: participation to SOP 2 (measurements and aircraft operations)
T0+30: delivery to database

Plan for LAUVA: Aerosol vertical mixing during the dry season based on coupled lidar-lidar and lidar - in situ airborne measurements

Laboratoire : LSCE

Coordinators :P. Chazette & F. Dulac

Scientific objectives:

Characterize biomass burning and dust aerosol properties (physical-chemical, hygroscopic and optical properties) along the vertical, their variability over dust production areas and in the vicinity of fires, their mixing during transport from source regions to the Gulf of Guinea

Methodological objectives:

- Combine downward and upward lidar measurements in lidar inversions in order to get rid of assumptions on aerosol optical properties.
- Test the interest of in situ and remote sensing aerosol instrumentation onboard a single aircraft (e.g. fixing levels for in situ measurements)
- Verify consistency (closure) between in situ aerosol characterization and lidar data.

Satellite product validation objectives:

- Verify consistency with coincident Aqua-Train aerosol products

Description of the work

LSCE is developing a new compact, eye-safe UV aerosols lidar (LAUV: Lidar Aerosols UltraViolet) in the frame of a CEA-Industry project. The prototype is going be shown to public during Pollutec salon to be held at Lyon in December 2004. During the first half of 2005, an airborne version (LAUVA: Lidar Aérosols UltraViolet aéroporté) will be tested onboard a Ultralight. This project is funded independently of AMMA. We propose to integrate LAUVA into the ATR-42 in order to participate to AMMA SOP-0, with the objectives described above.
In 2005, the work for AMMA will consist in integrating and testing the prototype lidar LAUVA (Lidar Aérosols UltraViolet Aéroporté) onboard the ATR-42, including a system allowing to change from upward to downward pointing during flight. A joint test flight is planned with AVIRAD and flying in coincidence with Leandre on board the FF20 is requested in order to test the airborne lidar-lidar coupling methodology.

Aircraft: ATR-42.

Number of requested flight hours:

- As far as possible SOP-0 flights are shared with LISA AVIRAD flights and coupled with SA FF20-Leandre flights. Minimum is 15 h for a Transect from Niamey towards the coast of the Gulf of Guinea, a flight over ocean and the return transect to Niamey.
- In 2005: 1 test flight from Toulouse over land and ocean common with AVIRAD test flight; FF20 with Leandre;

Description of flight plans (include scheme):

- SOP-0, Niamey, Feb. 2006: preferred conditions are low altitude flights with upward looking lidar under clear sky or low cloud coverage.
- Proposed test flight from Toulouse, autumn 2005: transit to ocean at top altitude with downward pointing; upward pointing during low altitude legs; end of flight at low altitude flying under track of FF20 with downward looking Leandre.

Complementarity with other airborne instrumentation (same aircraft) :
Closure with aerosol measurements (nephelometer, size distribution and chemical composition).

Coordination with other aircraft platforms (French and/or international):
Flights are as far as possible requested in near coincidence (track and hour) with FF20/Leandre and eventually other airborne lidars.

Coordination with ground-based station: coordination with ground-based lidars for coincident measurements (upward/downward looking depending on flight level).

Coordination with spaceborne platforms: near coincidences (track and hour) with CALIPSO and AQUA-Train

Logistic at the airport:
Internet access and phone/fax communication towards ground-based stations and other AMMA lidar teams.

Others
Need for printed meteorological satellite pictures and cloud coverage forecasts.
Large fire locations welcome

Deliverables

Airborne aerosol lidar onboard the ATR-42 for AMMA SOP-0.
Level-1 type: geometrically corrected backscattered lidar signal as a function of altitude and time.
Level-2 type: geolocated aerosol extinction vertical profiles, including level 2-a from classical lidar inversion and level 2-b from constrained inversion using coupling of lidar-lidar and or lidar-in situ measurements.

Milestones

- Qualification of the ground-based prototype LAUV: Dec. 2004.
- Test of the airborne version LAUVA on ultralight: summer 2004.
- Integration and test flight of LAUVA on ATR-42: autumn 2004.
- SOP-0: Feb. 2005.
- Level-1 data delivery: May 2005.
- First level 2a data delivery: Sept. 2005.
- First level 2b data delivery: March 2006.
- Publications: 2006-2007

Plan for CVI: Cloud particle and interstitial aerosol characterization in stratiform cloud layers

Laboratoire: LaMP
PI: A. Schwarzenboeck

Scientific objectives

Because of the large amount of dust present in the vicinity of the WAM (West African Monsoon), West Africa is an ideal region for investigating aerosol issues and assessing their impact on regional weather and climate. With respect to the aerosol research topic the AMMA project will focus on improving our knowledge of the physical, chemical, and radiative properties of aerosol particles, their temporal and spatial variability, and will assessment quantitatively the direct and indirect climate impact of dust. Furthermore, AMMA will study the impact of aerosol particles on specific meteorological phenomena, e.g. African easterly waves (AEW), mesoscale convective systems (MCS), and tropical cyclones. Finally, AMMA will focus on the weather and climate feedback onto aerosol sources, transport, and removal processes.

The key scientific objectives of the **AMMA** project with respect to the aerosol research topic are to:
- Establish the relationships between the chemical, radiative and cloud-nucleating properties of aerosol particles
- Assess the impact of aerosols on weather and climate over West Africa
- Characterize the effect of the WAM on aerosol sources, transport and removal.

With respect to the above presented aerosol related scientific objectives of AMMA the **CVI measurements (this contribution)** presented here focus on cloud particle and interstitial aerosol characterization in stratiform cloud layers during SOP-0 with particular attention given to the Twomey effect. During SOP-2 then the main objective is to understand microphysical, radiative as well as physico-chemical properties of boundary layer convective clouds, e.g. stratocumulus clouds downstream the MCS.

In more detail the presented contribution will allow to complete the aerosol measurements in cloudless situations (or simply out of cloud measurements) as the CVI mounted on the aircraft ATR-42 will give access to characterize all form of stratiform clouds in the WAM region that the aircraft ATR-42 might encounter: In particular the following research topics will be addressed:
Microphysics:
- Direct measurement of CWC (IWC, LWC)
- Measurement of cloud particle number concentration (equal to residual particle number concentration)
- From the above measurements: calculation of the cloud particle volume mean diameter which is a pretty good estimation of the effective diameter (Martin et al. 1994, etc.)

Radiation (Twomey effect):
- Change of optical cloud properties due to the presence of mineral aerosol particles = Twomey effect (caused by a change of the number concentration of CCN and/or IN)
- Measurement of the quantity of absorbing material in the cloud particles

Physico-chemical properties of aerosol particles in clouds:
- Chemistry and mass concentration of aerosol particle material dissolved in the cloud particles is depending on the cloud particle size (while varying cut-size of the CVI during flight)
- Role of mineral particles on the nucleation capacity of cloud particles
- Role of sulphate 'coating' of mineral particles (utilization of the thermodesorption)

Description of the work

Aircraft: ATR-42

Number of requested flight hours: 10 h in clouds during SOP-0 and 10 h in clouds during SOP-2

Description of flight plans:

SOP-0:

- During cloud presence: N-S flight profiles (track Niamey – Cotonou:) including climbs and descents between cloud base and cloud summit in case of extended stratiform layers.
- Combination with aerosol missions: Participation on 'aerosol flights' to account for 'occasional' appearance of stratiform cloud layers and thus, to sample with the CVI during cloud passages when the aerosol inlet has to be shut down.

SOP-2:

- During cloud presence: Planetary boundary layer profiles (profile lengths: 100-300 km) perpendicular to the MCS propagation to analyse smaller convective systems ahead and downstream (post-MCS stratiform clouds) the developing MCS (e.g. characterization of stratocumulus type cloud fields that may reach the Gulf of Guinea).
- Combination with aerosol missions: Participation on PBL 'aerosol' survey flights (perpendicular to the MCS propagation line) to sample with the CVI within cloud passages when the aerosol inlet is not operational due to cloud presence (principle as is presented above for SOP-0).

Complementarily with other airborne instrumentation (same aircraft): Complementary measurements on the aircraft ATR-42 of particle properties will be performed in cloudless conditions by a similar set of instrumentation downstream the aerosol inlet (e.g. 'veine communautaire'). Thus, while passing through partly cloudy regions the aerosol inlet and CVI inlet will complement each other and commutate to deliver a complete data set of aerosol particle properties without gaps.

Coordination with other aircraft platforms (french and/or international): Coordination of ATR-42 in-situ measurements with FR-F20 (RALI) measurements.

Coordination with ground-based stations: No particular demands others than installed EOP/LOP ground-based measurements (aerosol, radar etc.). The cloud in-situ instrumentation will detail obtained radar observations (onboard aircraft as well as routine ground-based radar network over land), as the planned flight-level measurements will sample properties of interstitial and in-cloud aerosol e.g. in the MCS vicinity.

Flying upon alert (minimum time): 1h

Logistic at the airport:

- Access to aircraft with groundpower during non-flight periods
- 1-2 working places
- Clean room facility to change filters
- Refrigerator for filter samples

Deliverables

The AMMA project is an instrument to support objective driven research, where the primary deliverable is new knowledge. The seasonal cycle of the WAM is promoted as an excellent example

for our understanding of WAM processes and the fidelity of dynamical models used for climate prediction.
The presented contribution of CVI measurement capabilities to operate in stratiform cloud conditions onboard the aircraft ATR-42 during SOP-0 and SOP-2 complements the measurement parameters of the aerosol instrumentation that will be operational in cloudless atmospheric conditions onboard the same aircraft and has to be seen in the overall synopsis with EOP/LOP observations to investigate the multiple-scale interactions and processes that determine the nature of the WAM. The described observations and analysis during the above SOP measurement campaigns will help to support research and prediction of weather and climate and its societal impacts in this region, to evaluate and improve models, and to maximize the use of satellite systems.

Milestones

October 31st 2005:	Proposal to INSU for flight hours in 2005 (certification process).
March 1st 2005:	ENVISCOPE will deliver the CVI inlet financed by CNES. Subsequent installation/adaptation on ATR-42. Inlet calibration tests.
Till May 31st 2005:	Simultaneous work to assemble/integrate CVI rack components. Notably Hygrometer and DMPS system. Programming of data acquisition and LabView guided flow regulation.
June 1st 2005:	All documentation of CVI inlet as well as CVI rack components ready for certification process. Subsequent test flight phase of the CVI inlet.
February 2006:	Participation SOP-0
July/August 2006:	Participation SOP-2

Plan for SAMU_MONA: Budget of peroxy radicals in the upper troposphere & regional export of chemical species

Laboratoire: *SA, LISA*
PIs: *Alexandre Kukui, Pascal E. Perros*

Scientific objectives

Budget of peroxy radical in the upper troposphere. Measurements of ROx radicals (HO_2, RO_2 and possibly OH) in the upper troposphere aimed at the identification of the ROx sources and sinks with the focus placed on the budget of ROx in relation to the convective transport of the oxidants precursors to the free troposphere and influence of these processes on the ozone production capacity.

Regional export of chemical species with a focus on the end of the monsoon period (SOP-3) for FF-20 when other aircraft will sample air masses over the Atlantic Ocean.

Chemical evolution of air masses in order to evaluate the convective system impact at synoptic scale in the lower troposphere (ATR42). The aim is to follow the modification of air masses that have been perturbed by deep convective system (effect on reactivity and on oxygenated compounds formation).

Description of the work

Aircraft : ***Falcon-20 and ATR 42 (Plus BaE 146)***

Number of requested flight hours SOP 2
FFalcon : 32 hours for HOx and O_3 local budget associated with MCS
12 hours for regional export of chemical species
ATR42 : 32 hours for HOx an O_3 budget associated with MCS
12 hours for evolution of chemical species in low troposphere
Description of flight plans (include scheme) (see 2004 proposal)

Complementarily with other airborne instrumentation (same aircraft) :
Need of HOx sources and sinks: NO_X, CO, O_3, H_2O, and VOC/OVOC measurements (P.E. Perros, C. Jambert, LISA)

Coordination with other aircraft platforms (french and/or international):
Low level local flights with French ATR-42 and mid-level flights with UK BaE-146 (to be discussed). DLR F20 might be only deployed in Dakar during SOP-3 (to be discussed).

Coordination with ground-based stations :
Ground based Doppler Radar if no airborne Doppler radar
Lightning detection network and SAOZ NO2 instrument in Djougou-Benin.

Flying upon alert (minimum time)
Normally about 60 min, needed the pumpdown, for the electronics (mass spectrometer power suppliers, chemical analysers) stabilisation and calibration of instruments.

Logistic at the airport
Chemical gas cylinders for SAMU (see instrument specifications): For each flight minimum 4 new gas cylinders (B5 ?) will be required. They should be either transported in advance to the airport or

prepared by making necessary mixtures in place using larger cylinders at higher pressure. The second option assumes availability in place of minimum instrumentation for preparing the mixtures (gas manifold system including pumping, pressure measurement end possibly gas cleaning).
For the campaign 4 gas cylinders for oxygen (B5) and one cylinder for air (N2/O2 B50) will be required. On the second hand we need a clean and air-conditioned room, used as a laboratory, located close to the parking of the aircraft. This room will be used for the change of VOC/OVOC traps, preparation of NOxTOy instrument and for in situ chemical analysis of VOC/OVOC samples.

Others

Three options are identified for the campaign depending of the SAMU instrument:

Option 1: OH, HO_2, RO_2 measurements - risk is high because gas inlet is complex (low turbulence and calibration kit for OH included in the inlet).

Option 2: HO_2, RO_2, measurements – risk is much lower because inlet is standard. Present cost estimate is for option 2 because cost for the complex inlet is not yet known.

Option 3: SAMU is not available for the experiment. The absence of direct HOx measurements during AMMA will limit the study of the fast chemistry of radicals which is the innovative phase of many recent experiment dedicated to the tropospheric ozone (for example PEM-Tropics B in the oceanic tropical region). However so little information is available over West Africa than the measurements of ozone and HOx precursors carried out on other platforms remain invaluable to assess the ozone budget following more traditional scientific approaches. Note that the FF-20 is likely to be the only aircraft equipped with trace gas measurements which will fly up to ~13km around the convective systems. Some on-board measurements of the FF-20 will be used to diagnose trace gas transport (CO, NOy, VOC). Complementary instrumentation (H_2O_2, HCHO, PAN) would be moved from ATR42 to FF-20, to provide a better description of the upper troposphere chemistry.

Deliverables

- Preparation of the instrumental package for chemistry studies on the FF-20
- Preparation of the instrumental package for chemistry studies on the ATR-42
- International coordination for flight planning during SOP-2
- Participation to SOP-2

Milestones

- Winter 2004: international coordination to define flight plans
- Spring 2005: All airborne instruments (except SAMU) ready
- Summer 2005: Test flight of airborne instruments (except SAMU) on FF-20 and ATR-42
- Fall 2005: SAMU instrumental package ready for test flight
- December 2005: test flight on FF-20
- Winter 2005: final tuning of the instrumental package
- Summer 2006: participation to SOP-2

4.2.1.2. ATMOSPHERIC DYNAMICS AND CLOUD SYSTEMS

Coordinator : Frank Roux

Participants: CETP, LA, SA.

4.2.1.2.a SOP-1

Coordinations: Turbulence and Flux measurements(F. Saïd), LEANDRE-2 (C Flamant),WIND (A Dabas)

Acronym : DRY-DYN

Complementary aircraft will be used to document the pre-onset and the onset of the monsoon, in terms of fluxes, turbulence and advection of humidity, and to investigate the interactions between the southwesterly monsoon flow in the boundary layer and the easterly Harmattan flow aloft in the transition zone (ITF : Inter-Tropical "Front")

SCIENTIFIC OBJECTIVES

The vertical structure of the mean and turbulent characteristics of the low troposphere during the onset of the Monsoon will be investigated with a focus on spatial scales interaction. The aim is to know how boundary layer turbulence interferes with the mesoscale forcing imposed by the Saharian Air Layer and by the African easterly jet and how mesoscale forcing disturbs the underlying Monsoon layer. The variability of land surface is another forcing that have to be considered as well as its time variability. The difficulty to distinguish between the south-north climatic gradient and the local or casual perturbations will be a challenge to solve : the aircraft, in relation with the ground stations, radar profilers information, radiosoundings, and drITFsoundings will provide real cases to numerical analysis.
More specifically, the following objectives will be addressed:

- To observe the interactions between the monsoon flow and local winds (WP 1.1.3).
- To study of the budget closure at the mesoscale, including the surface and atmospheric parts of the water budget with the large and meso-scale humidity advection, in particular during Monsoon onset phase (WP 1.2),
- To identify the fundamental relationships between evolving properties of the ocean and land surfaces, the planetary boundary layer, and the monsoon system, over the course of the annual cycle (WP 1.3)
- To investigate the impact of variations in land surface heating on the dynamics of the atmosphere, and the impact of atmospheric processes on the land surface state (WP 1.3),
- To assess the relative importance of rainfall variability due to both surface and atmospheric processes under the range of conditions experienced in the monsoon region (WP 1.3),
- To explain the role of tropospheric dynamical features such as the African easterly jet, dry intrusions, Saharan heat low dynamics and Saharan Air Layer (SAL) intrusions, on rainfall over the continent (WP 2.1),
- To determine the effects of MCSs and their degree of organization on the synoptic circulation through forcing of heat, moisture and momentum, the monsoon and harmatan flows, and the structure and evolution of the African and Tropical easterly jets aloft (WP 2.1),
- to investigate the microphysical, radiative and dynamical characteristics of dense and persistent tropical stratiform and cirriform anvils resulting from deep convective circulations (WP2.1, WP 1.2 and WP 2.4).

DEPLOYED AIRCRAFT AND INSTRUMENTS

- FR / ATR, for in situ measurements of fluxes and turbulence;

- FR / F20 (if available) for dropping sondes ;
- DE / F20 with WIND Doppler lidar, and - possibly - dropsondes ;

Aircraft	*Endurance (h)*	*Max altitude*	*Cruise speed*
FR / ATR	***6 h***	***25 kft / 7.5 km***	***200 kts (100 m/s)***
FR / F20	***5 h***	***42 kft / 14 km***	***400 kts (205 m/s)***
DE / F20	***4 h***	***42 kft / 14 km***	***400 kts (205 m/s)***

WORK CONTENT (5 years, SOP operations)

The strategy is to investigate the three following interfaces: surface, boundary layer top and Harmattan/Monsoon interface. As our knowledge of surface conditions is not sufficient to understand the interaction of the various flows such as monsoon, Harmattan, AEJ and their impact on the boundary layer, a vertical exploration by 4 airplanes is required. The FR/ATR will measure surface turbulence fluxes, the UK-Bae146 will measure turbulent fluxes mid-way through the PBL (the entrainment flux at the top of the PBL may be inferred from a combination of these measurements), while lidars onboard the DLR-F20 and F-F20 will be used to retrieve 3D wind fields and 2D water vapor mixing ratio fields underneath the aircraft. The aircraft will fly in formation, with the pair DLR-F20/F-F20 at about 600 hPa preceding the F-ATR42/UK-Bae146 pair, to be able to provide the boundary layer height to readjust the UK-Bae146 flight level. Momentum fluxes, sensible heat fluxes and latent heat fluxes will be measured by the FR/ATR within and slightly above the PBL. In addition to surface flux budget quantification and evolution, the presence, role and contribution of the coherent structures will be probed, as well as the relationship between entrainment, shear and organisations. Ozone emission and deposit will be studied thanks to the rapid ozone sensor mounted on the FR / ATR. For other trace gas and aerosols, the variability of the mean concentration will be measured. Chemical parameters will be used as tracers of the Saharian or monsoon flow. All FR/ATR flights will have to be performed near midday to minimize the diurnal cycle influence.
The airborne differential absorption lidar (DIAL) LEANDRE 2 will be flown onboard the FR / F20 during SOP-1. LEANDRE 2 will provide high-resolution (700 m horizontal, 300 vertical) measurements of water vapor mixing ratio in the lower troposphere at the mesoscale. LEANDRE 2 is operational since 1995, and has previously been used during the International H2O Project (IHOP_2002) field phase held over the Southern Great Plains in May and June 2002. It is worth noticing that the operation of LEANDRE 2 onboard FR / F20 is compatible with the release of dropsondes.
Developed through a French-German cooperation, the airborne Doppler lidar WIND flies aboard DE / F20. It provides vertical profiles of the 2D wind vector along the flight track, from the surface up to the flight altitude (about 7km during AMMA), with a horizontal resolution of 4 to 10km (depending on aerosol content), a vertical resolution of 250m, and an accuracy varying from better than 1 ms^{-1} to 2~3 ms^{-1} depending on the aerosol loading. It is worth noticing that the operation of WIND onboard DE / F20 is compatible with the release of dropsondes.
The participation of WIND to AMMA will be done in collaboration with DLR. At the present, the precise nature and volume of DLR contribution to the campaign has not been decided yet, but WIND has been clearly identified as one of the main objective for DE / F20 participation to the campaign. The precise number of flight hours devoted to WIND and their financial support will have to be discussed. 30 flight hours (15 h for science and 15 h for transit from Germany) should be available for WIND operations during SOP-1. The CNES and INSU have been solicited for buying an additional 23 flight hours for WIND.

The combination of LEANDRE 2 and WIND (water vapor and wind) would be a first. Such combination is highly desirable to improve our knowledge of monsoon-harmattan-AEJ interactions. It was shown in recent field campaigns devoted to the understanding of convection related processes (e.g. IHOP_2002 in which only LEANDRE 2 was involved, or VERTIKATOR in which only WIND was involved) that observational shortcomings were difficult to overcome.
WIND flights will be coordinated with LEANDRE 2 so that wind and water vapor fields can be observed simultaneously and horizontal water vapor fluxes can be derived. The benefit to the campaign should be extremely valuable.

Preliminary flight plans
During SOP 1, coordinated flights involving the FR / F20 (with LEANDRE 2), the DE / F20 (with WIND) and the FR / ATR are absolutely essential. In the following, preliminary flight plans for all involved aircraft are presented. During SOP 1, the FR / F20 and DRL / F20 would fly around 15-20 kft AGL, ideally above the African easterly jet (AEJ), while the FR / ATR will fly in the ABL.
Three types of flight plans are suggested:

- Documentation of the monsoon-Harmattan interactions : “ITF exploration”
- Documentation of the structure and dynamics of the monsoon flow (to be mutualized with ‘chemistry flights’): “Monsoon structure”
- Documentation of the latitudinal variability: “N-S transect”

- ***Flight plan 1 : ITF exploration***

The coordinated observations will provide the first detailed measurements in the Inter-Tropical Front (ITF) at the interface between the monsoon and the harmattan flows.
Part of the flight plan is a N-S transect (see figure 1 and 2) devoted to follow the latitudinal variability of the surface and atmospheric conditions according to the position of the ITF. This N-S transect will be performed in priority north of Niamey. The supersite closed to Niamey is located in Banizoumbou 60 km apart the transect (to the East). Efforts will be done to fly over this supersite after taking-off or before landing.
The composite analysis of Sultan and Janicot (2003) along a north-south axis (based on ECMWF reanalysis between 1968 and 1990) suggests that the ITF is generally located north of Niamey during the SOP 1 period. Nevertheless, the position of the ITF is highly variable and subject to a strong diurnal cycle. All involved aircraft will first take-off from Niamey and describe a north-south oriented transect designed to determine the position of the ITF. Real time LEANDRE 2 displays in the FR / F20 will be used to inform the FR / ATR on the depth of the monsoon layer and the position of the ITF. No real time display of the WIND data is available in the DE / F20 to inform the FR / ATR on the depth of the harmattan layer (the base and top of the harmattan layer are characterized by sharp gradients in wind direction separating the monsoon from the harmattan and the harmattan from the AEJ). Nevertheless such information can be provided by real time display of dropsonde measurements in the FR / F20.
If the Bae146 cannot participate, the question is raised about the opportunity for the FR/ATR to perform a saw-teeth flight plan instead of a straight level N-S leg. However this flight plan (figure 2b) would not enable us to obtain fluxes but only mean parameters (temperature, water vapor content, horizontal wind, radiative parameters, chemical parameters).
The interaction between the various flows in the region of the ITF (mesoscale study) will be analyzed with the help of vertical stacked legs flown by the F-ATR42 (and possibly Bae146), based on the information provided by LEANDRE 2. The aim is to flank the ITF with 2 or 3 vertical planes, with several legs performed within the PBL and one or 2 other above, to try in order to measure the upward and downward fluxes likely to occur in the shear area. Whenever the ITF is positioned at the latitude of the Gourma supersite (16°N), priority will be given to the vertical exploration of the IFT over the Gourma supersite.

The difficulty is that this type flight plan is time consuming for a single aircraft, so the UK/BAe (in figure 2b conditions) would be required for help. The ITF position will move toward the North during SOP1 and the best would be to document these flow interactions before the monsoon onset, just after and later. This amounts to 3 missions (two flights for each) for a total of 24 h for the F20s and 30 h for the ATR.
While the FR / ATR probes the 3 vertical plans (fig. 2) in the vicinity of the ITF, the DE / F20 and FR / F20 will fly coordinated rectangular patterns above the AEJ level, in the vicinity of the FR / ATR flying area, going back-and-forth across the ITF (i.e. its position on the ground) to document the diurnal variability of the ITF position. The FR / F20 will drop sondes every 1° along the north-south oriented legs and at the corner of each rectangular box pattern performed in coordination with the DE / F20.
Given the endurance of the FR / ATR (6 h), FR / F20 (5 h) and the DE / F20 (4 h), refueling issues should be carefully considered whenever the ITF is north of 17°N. Coordination with other aircraft: close coordination with the DE / F20, the FR / ATR is essential.

- ***Flight plan 2: "Monsoon structure"***

For mesoscale investigation purposes, another flight plan is also suggested for the two low level aircraft (including the FR/ATR) in order to reach a better understanding of the monsoon layer (figure 3). The flight would be performed in the vicinity of Djougou where the Doppler RONSARD radar is located, to document the organization of convection in the PBL in cloud free conditions. Both aircraft would describe a cross-legs pattern (2 orthogonal vertical plans consisting of 5 horizontal legs: 3 in the PBL, 1 in the harmattan layer and 1 above, see figure 3) to be able to sample the main organized structures along their main directions.
The RONSARD scientists will inform the FR / ATR scientist whether organized convection is being observed in real time. If the FR / ATR does pursue with the X-legs pattern in Djougou, the DE / F20 and FR / F20 will conduct a coordinated rectangular pattern around Djougou to wait for the FR / ATR. Another alternative is to perform this flight plan in the vicinity of Niamey, where the American doppler Radar S-Pol is likely to operate.
The FR / F20 will drop sondes every 1° along the north-south oriented legs and at the corner of each rectangular box pattern performed in coordination with the DE / F20 when the FR / ATR performs the X-legs pattern.
Close coordination between the FR / F20, DE / F20, and FR / ATR is essential. This type of flight also fulfills the needs for chemistry measurements over the CATCH window.
This flight plan will be coordinated with ground-based measurements performed in the CATCH region, in particular over sites equipped with remote sensing instruments measuring humidity and wind in the troposphere, as well as sounding sites. The launching of constant level balloons (CLBs) from a surface site (western Ghana) will also need to be coordinated in time with the aircraft.
Two flights of this second kind will be made, that represent10 flight hours for the ATR and 8 for the FR/F20 and DE/F20.

- ***Flight plan 3: "NS transect"***

A third flight plan will be considered in order to document the monsoon, harmattan and AEJ structure along the longest possible north-south oriented leg and to measure surface fluxes for both GCM and mesoscale models. In this case, no vertical plane will be probed as explained previously. All involved aircraft (namely the DE / F20, the FR / ATR and the FR / F20) will first take-off from Niamey and head north to describe a north-south oriented transect before turning around to head south towards Cotonou. The northern most extend of the transect will be determined by the endurance of the DE / F20 (4 h). The journey from Niamey to Cotonou being approximately 2 h, the 4 aircraft will fly to the north for approximately 1 h (somewhere half-way between Niamey and Bouressa), before turning around and depicting the structure and dynamics of the lower troposphere

all the way to Cotonou. Real time LEANDRE 2 displays in the FR / F20 will be used to inform the FR / ATR on the depth of the monsoon layer. The FR / ATR, FR / F20 and the DE / F20 will then stop in Cotonou to refuel. After refueling, the FR/ATR and the FR/F20 will fly to the south over the ocean (as far as 2°N) in order to check the variability of the sea surface fluxes in the Guinean Gulf. This extension will be coordinated with the N-S transect of the FR- R/V ATALANTE research vessel. The FR/ATR will measure surface fluxes while the FR/F20 will provide the 2D cross-section of water vapor mixing ratio (LEANDRE 2) and thermodynamic variables (dropsondes). The excursion of the ocean shall be on the order of 2 h (round-trip). Upon heading north towards Niamey, the aircraft will be joined by the DLR/F20 to cover the transect between Cotonou and Niamey.
Concerning the northern part of the transect (north of Niamey), the objective is to study the saharan heat low more thoroughly. There are two options: (a) overpass of the Gourma supersite (16°N) and (b) flight in the direction of the Tamanrasset climatic station (radiative budget measurements at the surface, sounding) with the TReSS remote sensing platform being installed (backscatter lidar and sun photometer measurements would then be available in addition to the routine measurements in Tamanrasset). If 2 flights can be performed, the best conditions would be before the monsoon onset and after the 'monsoon jump'. If only one such transect can be made, the priority will to describe the conditions prior to the monsoon onset in order for the measurements to be used to initialize mesoscale models and GCMs. In this case, one N-S transect will be covered by two IOPs, that represent 9.5 flight hours for the FR/ATR, 8 for the FR/F20 and FR/ATR, and 6 for the DLR/F20.

DISTRIBUTION OF THE FLIGHT HOURS THROUGHOUT 3 DIFFERENT TYPES OF MISSIONS

	ITF exploration	**Monsoon structure**	**N-S transect**	□
SOP-1.ATR. NS-DYNAMICS	30 h	10 h	9.5 h	49.5h
SOP-1.FR/F20. NS-DYNAMICS	24.5 h	8 h	8 h	40.5h
SOP-1.DE/F20. NS-DYNAMICS	24 h	8 h	6 h	38h

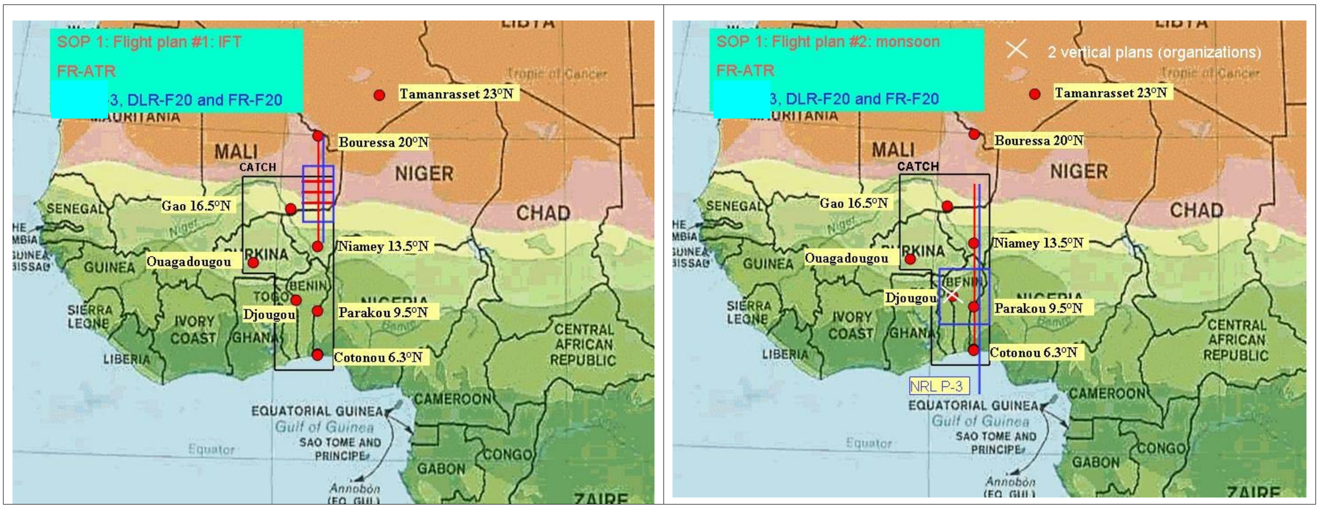


Figure 1 :Schematic flight tracks during SOP1. Vertical planes and cross-pattern are indicated, see figure 2 and 3 for more details.

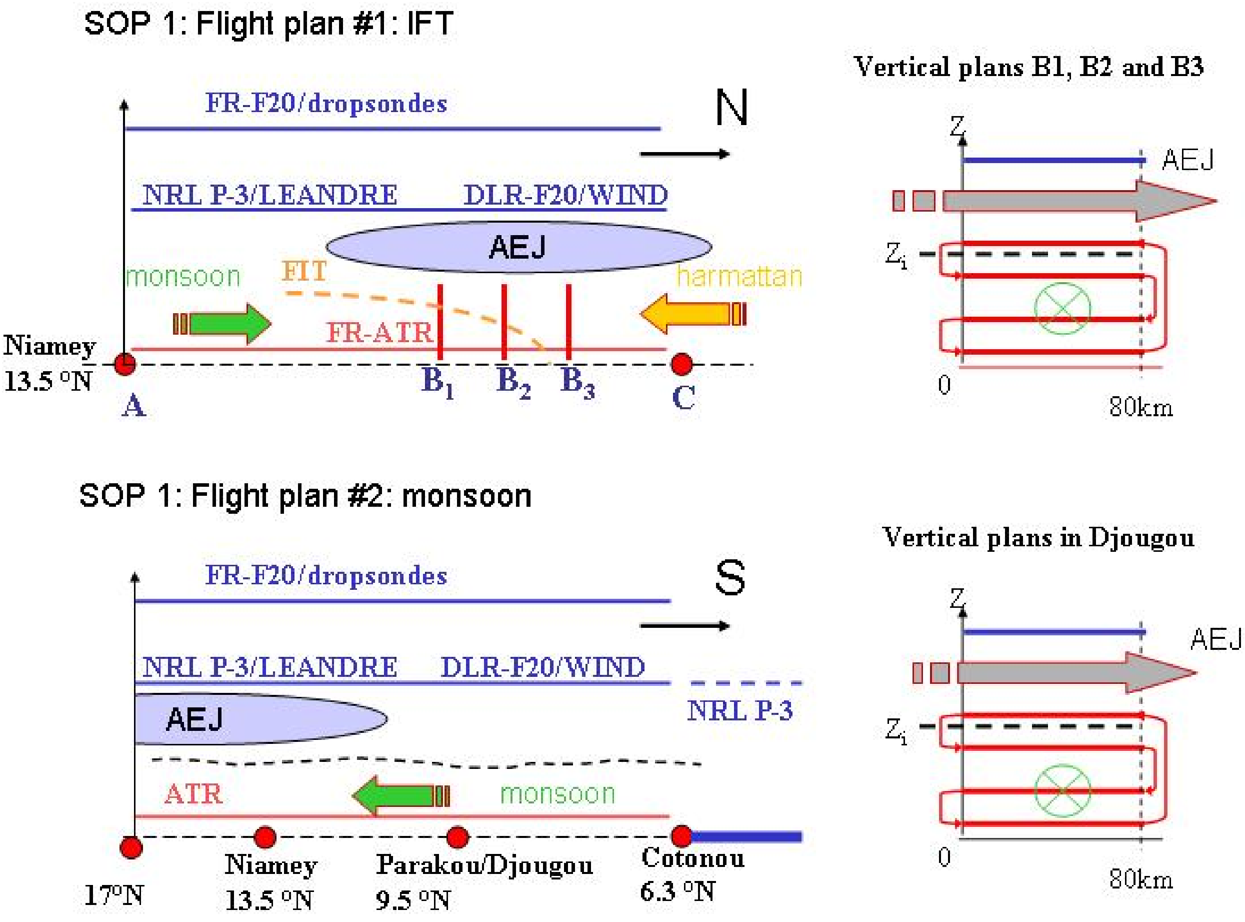


Figure 2 : Schematic flight tracks during SOP1. Top : N-S transect flown by all aircraft. Bottom : vertical plane flown by the FR/ATR at B_1, B_2 and B_3. Ideally, type 1 and 2 missions should be flown on back-to-back days

Deliverables

During the first 6 months (January – June 05)

- Upgrade of LEANDRE 2 ;
- Analysis of flux and turbulence data collected during test flights with the FR / ATR ;
- Planning of the aircraft operation during SOP-1 for addressing the objectives of WP1.2, WP1.3 and WP2.1 relevant to the water cycle, surface-atmosphere feedbacks and atmospheric dynamics ;

During the next 18 months (July 05 – Dec 06) ;

- Ground tests of WIND (late 2005 or early 2006)
- Integration of LEANDRE 2 onboard FR / F20 (late 2005 or early 2006) ;
- Integration of WIND onboard DE / F20 and flight test (May 2006) ;
- Preparation of the LEANDRE 2 operation in Africa
- Perform measurements during the SOP
- Data processing and preliminary analyses
- Delivery of data to the database

Milestones

T0: 1 June 2004
T0+12 mo: Planning of the aircraft operation
T0+18 mo : WIND successfully operated at ground
T0+21 mo: Integration of LEANDRE onboard FR / F20, Integration of WIND onboard DE / F20
T0+24 mo: Participation to SOP-1 (measurements and aircraft operations)
T0+30 mo : Delivery to data base

WORK CONTENT (2005)

The first year of the project will be devoted to ensure the readiness of the airborne instrumentation and aircraft platforms involved and to planning of coordinated scientific sorties for each individual aircraft and jointly with other aircraft as well as with ground-based observations.

The work necessary to insure successful coordinated campaigns with the different aircrafts during the SOPs will be:

- Organisation of dedicated “ SOP aircraft” meetings;
- Definition of observation strategies in coordination with WP which will be the future data users, coordination with ground-based observations, coordination with European PIs for aircraft strategies;
- Preparation of the experimental plan describing the scientific objectives and the coordinated flights to be conducted, depending on the atmospheric conditions;
- Preparation and readiness of the airborne instrumentation;
- Use of results from numerical simulations (WP_4.1) to test and validate the sampling strategies.

Concerning LEANDRE-2 :

LEANDRE 2 is currently undergoing an unprecedented upgrade. Many of the spare parts have been used during of IHOP_2002 due to tough operating conditions (high temperatures, overheating during long flights in the ABL and heat evacuation problems, etc..). An upgraded version of LEANDRE 2 - LNG - shoulb be operational in 2005.

Pre-SOP activity concerning LEANDRE 2 will consist in:

- Upgrading LEANDRE 2
- Installing LEANDRE 2 in the FR / F20 for test flights

Concerning WIND :

After extensive operations of maintenance in 2003 (with the refurbishment of the laser transmitter in particular), WIND will be tested at ground in 2004 for a complete check-up.

In late 2005 or early 2006, WIND will be integrated at DLR and functionally tested at ground. The integration of the system aboard DE / F20 will be carried out the week before WIND starts participating to the campaign. The details of the integration (probably at DLR) have still to be worked out, but a test flight will be necessary.

Deliverables

- Fully prepared airborne equipment for SOPs (including test flights if needed)
- Delivery and installation of airborne instrumentation
- Aircraft SOP contribution to scientific, experimental and logistical planning, coordination with other airborne platforms and ground-based sites

4.2.1.2.b SOP2 & SOP3

Complementary aircraft will be used to document the internal structure of Mesoscale Convective Systems (MCSs) of different size and intensity at various stages of development, their evolution and propagation, in relation with the atmospheric environment (kinematic flows, convective instability, tropospheric humidity, synoptic scale perturbations, …) over the continent and at the transition between the continent and the tropical eastern Atlantic ocean.

SCIENTIFIC OBJECTIVES

Objectives to be adressed, through coordinated observations with airborne Doppler radar(s) and dropsondes during AMMA SOP-2 and 3 concern :

- The efficiency of MCSs as rain producers transforming atmospheric moisture into precipitation (WP_1.2) ;
- The structure and evolution of three-dimensional convective and mesoscale circulations within MCSs of various size, intensity, and at different stages of their lifecycle (WP_2.1) ;
- The horizontal and vertical transport, internal mixing and entrainment/detrainement rates for application in atmospheric chemistry (WP_2.4) ;
- The structure and evolution of Mesoscale Convective Vortices (MCVs) developing in the trailing stratiform region and their role in favouring the regeneration of MCS, and the transition toward tropical cyclogenesis (SOP-3) (WP_2.1) ;
- The two-way interaction between MCSs and their environment (AEJ and AEWs), i.e. how ambient kinematic and thermodynamic characteristics control the size, intensity and lifetime of MCs, and how the MCS-induced sources of heat, moisture and momentum modify the environmental profiles and the wave activity (WP_2.1) ;
- The interaction between MCS and the boundary layer, i.e. to estimate the available energy in the boundary layer that is likely to feed the convective or squall line systems : how does the energy accumulate, what is the effect of the wind shear between the monsoon flow and the drier easterly air above, how does the boundary layer recover equilibrium again after a squall line event ? (WP_2.1);
- The microphysical and radiative characteristics of dense and persistent tropical anvil clouds resulting from deep convective circulations (WP_2.1).

DEPLOYED AIRCRAFT AND INSTRUMENTS

AMMA-SOP 2 and 3 will use complementary aircraft to document the internal structure and evolution of West-African MCS and their interaction with the environment.
The US / NOAA-P3 *(provided that US participation to AMMA SOP is confirmed)* will be used primarily top make low-to-mid levels (2-20 kft AGL) Doppler radar observations and in-situ measurements of state parameters in the vicinity of (and - if flight safety permits - within) mesoscale convective systems. Observations by the turboprop aircraft will focus on three-dimensional air circulation, precipitation and cloud microphysical structure.
During SOP-2, the FR / ATR will be used for in situ measurements of wind, heat and moisture contents, turbulence and fluxes in the low troposphere, before and after the occurrence of MCS.
The FR / F20 will be used to make GPS dropsonde measurements close to and in the mesoscale environment of MCS. With a 4-channel GPS dropsonde system, the minimum spacing between dropsondes is about 50 km. During SOP-3, RALI (94-GHz Doppler RASTA radar and LEANDRE-2 3-wavelength lidar and in-situ microphysics probes) will be used to document the three-dimensional dynamic, microphysical and radiative properties of stratiform and cirriform part of MCS anvils.
The US / NOAA-P3 Tail Doppler Radar is an airborne, dual beam, meteorological research radar that has been used extensively in the continental US and various regions around the world. Equiped with the « French antenna », its two antennas extend back from the tail of the aircraft and spin about the longitudinal axis of the aircraft. One antenna points slightly ahead of the aircraft and one slightly

aft. As the aircraft translates the antennas through space the Doppler radar traces two conical helixes through the atmosphere, essentially observing all of the atmosphere with two separate looks within 50-100 kilometers of the aircraft.
The fore and aft looks yield two wind components for each location in the atmosphere. Applying the conservation of momentum and mass, a 3-dimensional structure of the atmosphere is produced which can then be sliced through any axis to produce two dimensional plots.
The US / NOAA-P3 aircraft has three radars: nose, lower fuselage and tail. The nose radar (a solid-state C-band radar with a 5° circular beam) is used strictly for flight safety and is not recorded for research purposes. The lower fuselage provide a horizontal view of precipitation at a maximum range of 400 km, which is crucial for real-time aircraft operation in the vicinity of intense precipitating systems. The aircraft and radars characteristics are :

NOAA P3 Characteristics

Endurance	Max altitude	Cruise speed
8.5 h	25 kft - 7.5 km	230-280 kts 115-140 m/s

NOAA P3 radars characteristics

Device	Parameter	Units	Lower Fuselage	Tail Doppler
Transmitter	Frequency	MHz	5370	9315
	Wavelength	cm	5.59	3.22
	PRF	µs	200	3200+2133
	Pulse Length	m	6.0 (1800 m)	0.5 (105 m)
	Peak Power	kW	70.0	60.0
	MDS	dBm	-102	-111
Antenna	Hor. Beam Width	deg	1.1	1.35
	Vert. Beam Width	deg	4.1	1.90
	Gain	dB	37.5	40.0
	Polarization	N/A	linear (horizontal)	linear (vertical)
	Stabilization	deg	±5 (pitch, roll)	±25 (pitch, drITF)
Radar	Velocity Nyquist interval	m/s	N/A	51.6
	Maximum unambiguous range	km	N/A	93.75

The major drawback of the Tail radar is the 3.22 cm wavelength (X-band) and high PRF. X-Band radars suffer from intervening rain attenuation which limit the maximum range at which Doppler estimates are obtained. This problem is remedied by flying close to the area of interest, reducing the distance the beam has to travel through the intervening rainfall. The high PRF, coupled with the short wavelength result in a low velocity Nyquist interval and unambiguous range. The low Nyquist velocity is the hardest of the two to compensate for as intervening attenuation minimizes problems with second trip echoes. The low Nyquist velocity can be overcome through unfolding utilizing the measured component of the air velocity along the radar beam at the aircraft as a first guess, and recently by using a dual-PRF.
The Vaisala Dropsonde system to be installed onboard FR / F20 represents the latest in dropsounding technology with an onboard dropsonde microprocessor and synthesized digital transmission. The Vaisala Dropsonde RD93 measures and transmits pressure, temperature, relative humidity and wind data to the receiving system at a high data rate. The receing system processes the data, displays it and stores it to the hard disk.

The main features of the Vaisala dropsondes system are :

- Operates to an altitude of 24 km
- Operates in both polar and tropical environments
- Operated by one person

- Four-channel data system allows dense horizontal dropsonde spacing
- Can be deployed at indicated airspeeds up to 250 knots
- Descent time: approx. 15 min from 14 km, 8 min from 7.5 km
- 2 Hz sample rate for wind and thermodynamic data
- Preparation time <2 min

Concerning RALI and in-situ microphysical probes onboard FR / F20 during the SOP, the proposed strategy relies on an upscaling of the MCS anvil properties from the in-situ documentation inside the anvil to the documentation of the cloud properties at the scale of the West-African monsoon system. Remote sensing measurements from ground-based (ARM mobile facility or equivalent radar/lidar/radiometer set of observations, with for instance Ronsard, X-port and bistatic antennas), airborne (RALI, IR radiometers) and satellite (the A: Train: CALIPSO/CloudSat/Aqua, DMSP, and may be TRMM) platforms are new tools which will help us understand how MCS anvils impact regional and global radiation and water budget and chemical processes by absorbing chemical species.

From ground-based active instruments that will provide a mesoscale description of dynamics and thermodynamics of the system with some complement on microphysics of precipitation and the airborne and spaceborne active instruments (cloud radar and lidar) will allow a 3D documentation of the vertical stratification of the cloud properties on mesoscale for a limited amount of cases, we should be able to document a rather complete water and energy budget. The ground-based observations will provide statistically-representative documentation of this vertical stratification of clouds properties at high temporal resolution and on a longer time scale than the airborne observations. The spaceborne active instrumentation will then be used to extrapolate the cloud properties from local scale / long time series (ground-based) and mesoscale / case studies (airborne) to regional (West-Africa) and global scales. The simultaneous cloud documentation by ground-based and airborne facilities will allow us to assess the representativeness of the 3D airborne representation of a limited number of cases within the climatology that can be built from the ground observations. Conversely, the airborne documentation will serve as a validation for the space-time conversion of ground-based observations. Furthermore, the set of « rain » radars will give a description of the dynamics within the precipitating part of the anvil that will allow to make the connection with thermodynamics and microphysics.

This ground-based and airborne documentation will be evaluated using in-situ microphysical sensors onboard the same aircraft. Then, the spaceborne retrievals of the ice species properties from the active and passive sensors will be validated using ground based-facility on a more statistical basis. However, the spaceborne active measurements alone are not sufficient to work at the scale of the African monsoon system. The passive remote sensing measurements from space (e.g. Aqua/MODIS, Aqua/AIRS, TRMM/TMI...) benefit from a much larger swath but are integrated measurements in the vertical. The clue here is therefore to constrain the retrieval methods from passive instruments with the active measurements during AMMA (RALI/ARM mobile facility, Ronsard, Xport, Bistatic antennas), and then to extrapolate the active remote sensing documentation of the cloud properties to the swath of the passive instruments. Once constrained during the AMMA-SOP the satellite products could be exploited for other monsoon seasons the A-train and other satellites will document.

RISK AND CONTINGENCY PLANS

In case the US / NOAA-P3 will not participate in the AMMA SOP, this scientific objective would only rely on ground-based radar observations and dropsonde survey with the FR / F20.

WORK CONTENT (5 years)

A) MCS-DYN: MCS DYNAMICS AND ENVIRONMENT

Coord F. Roux

The dual-Doppler networks to be installed near Djougou (Benin) with the two French X-Port and Ronsard radars, and near Niamey (Niger) with the two US TOGA and S-Pol radars, will provide a temporally continuous record of MCS structure through the experimental period. However they only sample the MCSs during their passage over a relatively small area. The aircraft (based in Niamey) will extend the dual-Doppler coverage and follow the MCSs in order to cover their life cycle more completely. In particular, the aircraft can follow an AEW system as it tracks westward, using Dakar as a recovery airport if needed. Following an AEW for several days will be essential for documenting the role mesoscale convective vortices (MCVs) play in generating local vorticity that may help to trigger new convection over the continent (SOP-2) and to facilitate tropical cyclogenesis over the ocean (SOP-3).

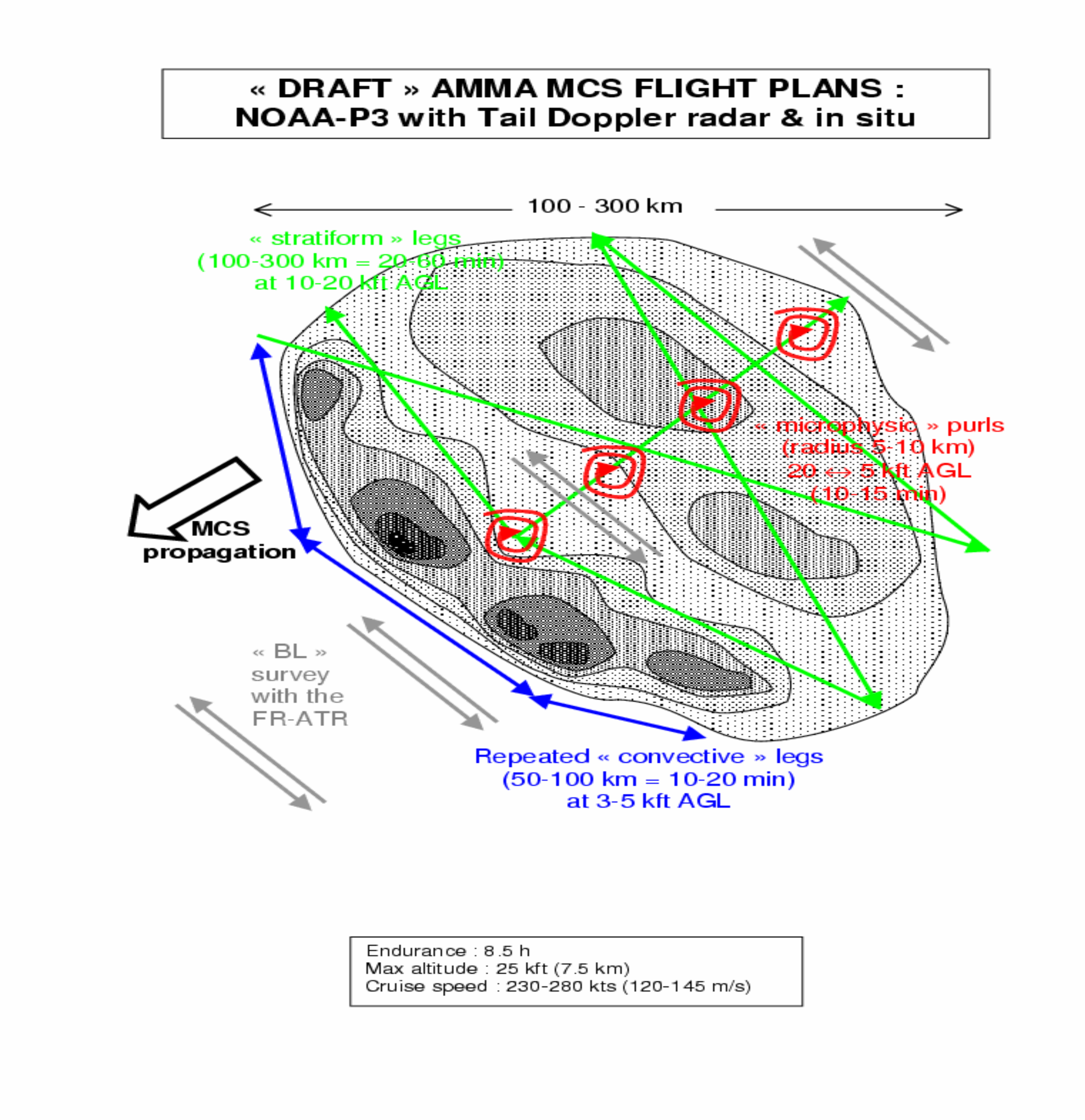
The US / NOAA-P3 flight patterns will largely be determined by the scanning methodology of the Doppler radar. This is an X-band system, which limits the useful range to a maximum radial distance of about 45 km from the aircraft. The radar system employs a multiple PRF to extend the radial velocity Nyquist interval to >50 m/s. The US / NOAA-P3 radar antenna is mounted in the tail of the respective aircraft, and it utilizes the « fore-aft » scanning technique. Horizontal data spacing is 1.4 km.

Preliminary proposals for generic flight modules according to the above mentionned scientific objectives could be as follows (see the Figures below) :

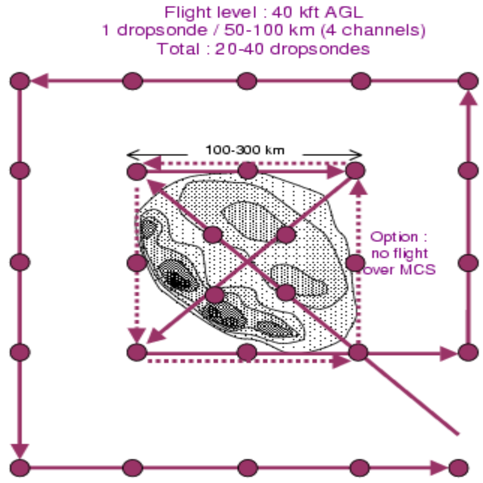
- **Leading convective region of MCS :**Ahead of the leading line (generally to the west of a westward moving MCS), the US / NOAA-P3 will fly patterns roughly parallel to the line. Leg length should be 50-100 km to allow multiple repeat at a small section of the line, or long enough to encompass most of the leading edge. Altitude will be as low as possible (3-5 kft AGL) to maximize viewing of the surface convergence along the leading edge.
- **Trailing stratiform region of MCS and MCVs :**the US / NOAA-P3 will then map the region to the rear - i.e. to the east - of the convective line. Of particular importance are the mid-level rear inflow and the development of a mesoscale vortex. Basic altitude will be 10 kft, but other altitudes are possible if microphysics data sets are desired (e.g. between -10 and +10 °C, with the 0°C isotherm at about 15 kft in West Africa). For a limited number of situations, special flight modules (microphysical « purls ») will also be executed to examine more closely the interaction of the rear inflow with the hydrometeor microphysics. A lagrangian spiral up and/or down, with a radius of 5-10 km between 20 and 3 kft, (a « purl ») is the best strategy for an extensive and strong stratiform region.
- **MCS environment :**Basic altitude for the FR / F20 will be as high as possible (40 kft AGL). This aircraft will first deploy sondes near (or within if weather conditions and flight safety permit) the MCS, then it will fly a larger box encompassing the MCS, at a distance of 100 to 300 km. Dropsondes will be released every 50-100 km. Coordination will be sought with operations of the radiosonde arrays to be operated during the AMMA SOP [e.g. Southern quadrilateral : Cotonou (Benin), Parakou (Benin), Niamey (Niger), Tamale (Ghana), Minna or Abuja (Nigeria) ; Northern quadrilateral : Parakou (Benin), SOP_RS1 (location east of Niamey to be determined) (Niger), Timbuktu or Gao (Mali), Ouagadougou (Burkina Faso), Niamey (Niger) ; Western quadrilateral : Bamako (Mali), Dakar (Senegal), Sal (Cape Verde), Conakry (Guinea), Nouakchott (Mauritania)], and with possible « drIftsondes » operations (from N'Djamena/Chad or Bangui/Centrafrica)
- **Evolution of the boundary layer :**the FR / ATR will fly legs in the boundary layer (1-5 kft) in the upstream environment, in the trailing stratiform region (if possible) and in the wake of the MCS to document the evolution of the thermodynamic characteristics. The vertical structure of the mean and turbulent characteristics of the boundary layer will be described once before and a few times after a MCS went through Niamey or Parakou, so that the response time of the surface and boundary layer can be studied, as well as the retro-effects on the MCS. The emission and deposition of ozone will be also measured, as well as the spatial and time evolution of the mean concentration of other trace gaz and aerosols. Energy and water budget will be estimated for systems smaller than 100 km. This can be hardly

done with an unique aircraft : it is essential that another aircraft couple the FR / ATR, so that the temporal variability can be minimized. Depending on the position of the MCS, the flight will occur in the vicinity of Niamey or Parakou.

- « **Chemistry flights** » **:**In order to understand the relations between MCS dynamics and precipitation, and the local evolution of atmospheric chemistry (aerosols and gases), coordinated flights will be conducted with the DE-F20 and the UK-BAe146 (and the FR / F20, if not devoted to dropsonding)

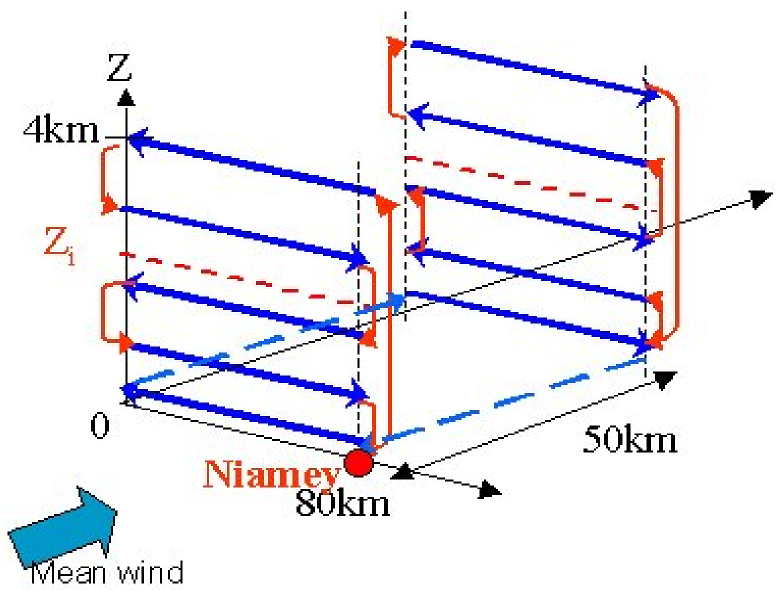


« DRAFT » AMMA MCS FLIGHT PLANS : FR-F20 with dropsondes



The external « box » should be at 100-300 km from the internal one, depending on the MCS size

Endurance (FR-F20) : 5 h
Max altitude : 42 kft (14 km)
Cruise speed : 400 kts (205 m/s)



« DRAFT » AMMA MCS FLIGHT PLANS : FR / ATR for pre- and post-MCS BL measurements

B) *ANVIL-ICE : ANVIL ICE MICROPHYSICS*

Coord. D. Bouniol

Deep convection is the ultimate source of tropical upper tropospheric extended clouds, i.e. tropical anvils. The anvil lifetime, typically 6-12 hours, exceeds the duration of deep convection by many hours. Far from the active centre of the convective core the anvil structure becomes optically thinner but still has a significant radiative impact. The microphysics of ice crystals within this type of clouds systems is an important parameter impacting radiation budget, the amount of water stored in ice phase within the troposphere and chemical concentrations for soluble species and species that adsorb onto ice. Regarding more specifically the African Monsoon mechanisms, the convective anvils, through their modification of the atmospheric dynamics on a large area, is expected to play a significant role of modulation of some of the monsoon components (e.g. Modulation of the subtropical jet, warming of the upper troposphere, modification of the radiative budget, dynamical feedbacks with the convective part of the squall lines, moistening of the environment of the convective anvils, modification of the precipitation efficiency…). The magnitude of this modulation is completely unknown. Its quantification is a major objective of this project.
The anvil cloud properties are strongly variable in space and time, and this is the main reason why the impact of such clouds on climate and the global circulation is still so poorly known despite some important effort already done for studying mid-latitude ice clouds. Indeed, within the last fifteen years almost 10 intensive field experiments have been settled to document mid-latitude ice clouds in USA and Europe, and very few in the tropics (CEPEX, SUCCESS, CRYSTAL-FACE) because of technical difficulties to reach high altitude clouds at those latitudes. Some information on the shape, size and sedimentation of crystals has been gathered during these previous campaigns, and it is proposed here to take advantage of these measurements and methodologies to deploy a specific observation strategy benefiting from satellite observations planned at the horizon of 2005 (active and passive remote sensing, vertical sounding …) and perform closure analyses on water and radiation budgets through a comprehensive observation to modelling approach. A single aircraft must be deployed in the field during AMMA SOP, equipped both with RALI and a set of in-situ microphysical sensors. The flight strategy needs to include ground-based site overpasses. These flights must also be coordinated with overpasses of the A-train (CALIPSO/CloudSat/Aqua) or passive and active precipitation instruments (TRMM/PR and TMI, DMSP/SSMI) in order to compare the physical products deduced from the different statellite sensor combinations (CloudSat/CALIPSO, Aqua, PARASOL) with in-situ and active ground-based and airborne measurements.
This airborne instrumental combination provides the ice water content, effective radius, ice terminal fall velocity, ice density and particle size distribution within the common sampling area at a resolution of 1 km horizontally and 60 m vertically. However when cloud becomes too optically-deep the lidar will not traverse. In this case the same parameters can be deduced by using only the Doppler radar measurements at a resolution of 150 m horizontally and 60 m vertically, but with a slightly degraded accuracy (around 35-40 % for the ice water content and effective radius). Moreover the RASTA radar is a Doppler system with a simultaneous sampling at zenith and nadir and a multi-antenna system allowing to retrieve the three-dimensional wind field below the aircraft, and the two-dimensional wind field above the aircraft. The vertically-pointing antennas provide a measurements of the terminal fall speed of hydrometeor and vertical air velocity (above and below the aircraft). The concept of radar/lidar synergy has been tested during CLARE 98 and CARL 2000 and is implemented continuously from ground since october 2002. Integration of RALI and test of the instruments will be performed between august and september 2005 on the Falcon 20.

More precisely the following documentation should be achieved with the airborne instrumentation:

- Documentation of the internal structure of the tropical anvils and their evolution
    - macrophysical properties : cloud overlap, horizontal and vertical heterogeneity
    - microphysical properties : vertical distribution of particle habit, crystal size, terminal fall velocity, and crystal density

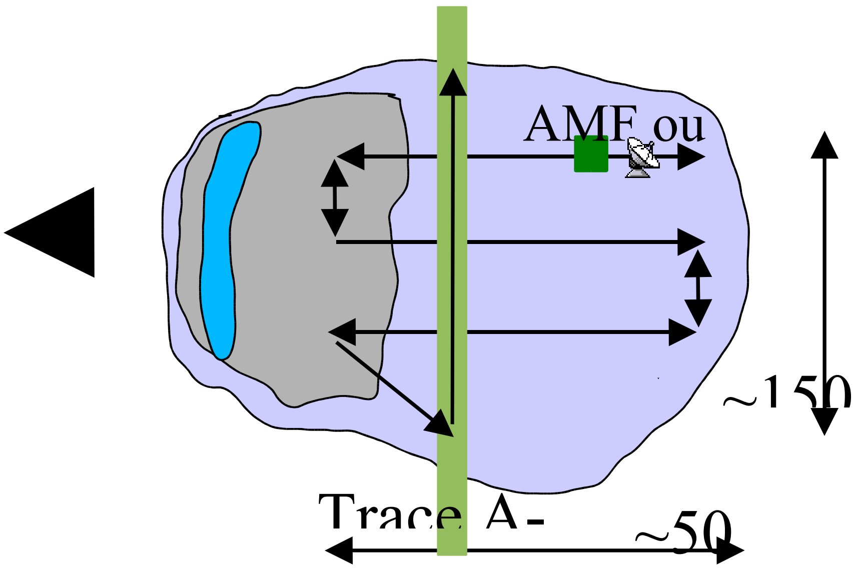
- dynamical properties : 2D/3D wind, PV (Potential Vorticity), horizontal and vertical transports, variation of wind intensity within the different parts of the tropical anvil (convective, transition anvil, cirrus anvil)

➢ Documentation of physical processes involved in the anvil life cycle
  - microphysical processes: aggregation, evaporation, condensation, sedimentation...
  - dynamical processes: transports, PV diagnostic
  - radiative processes: implication on the diurnal cycle and surface fluxes that govern the re-evaporation of precipitation

➢ Documentation of the contribution of the tropical anvils to the water budget

In the following two flight strategies are described in order to complete this documentation. The first one is called mesoscale structure flight and its main goal is to obtained a three dimensional description of the internal structure of the MCS anvil and thus to derive physical properties at the scale of the anvil, the second one is called vertical structure which main objective is to document the vertical layering of microphysical properties.

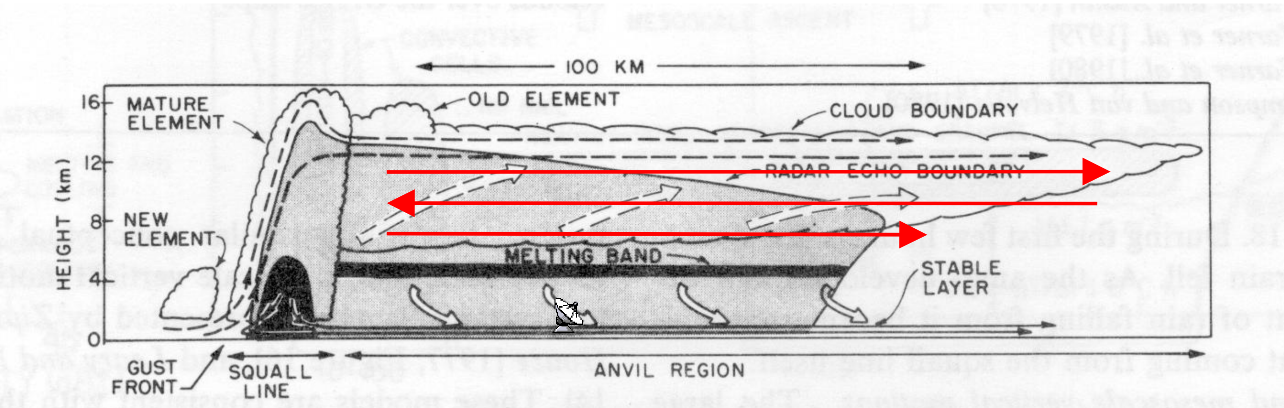
Mesoscale structure flight



This flight plan consists in three legs of about 540km (45' minutes assuming the F20 speed is 200 ms^{-1}) aligned with the propagation direction of the MCS at the same altitude (as high as possible: about 11-12 km for the F20) separated horizontally of about 50 km, sampling the stratiform and cirriform region of the MCS, with one overpass of ground based facility (ARM Mobile facility, Ronsard and Xport sampling area for instance). The remaining time of the mission will be used for taxi to the airport, inter-leg flight (about 15') and depending of satellite coincidences to flight within the satellite overpass.
Such a flight plan will allow to document the transverse variability of the MCS in terms of microphysical, radiative and dynamical properties since three vertical cross-sections will be sampled. It should be mentioned, that the “climatological” dominant propagation direction of MCS will be westward. The active spaceborne instrumentation that will be launched in 2005 is on a polar orbit. It is then expected that this sampling strategy will provide a transverse documentation for the active remote sensing 2D documentation, that will be used in order to exploit the passive remote sensing measurements.
By using assimilating tool developed in the framework of WP4.1.1 (MANDOPAS) the simultaneous use of these three legs will give access to a mesoscale description of the MCS anvil allowing to compute the diagnostic parameters and the different terms of the water budgets, concerned by the ice phase (input for WP1.2). These 3D-images can be seen as an instantaneous image of the system (as can be obtain from a model output), thus by degrading this image at

different model scales (CRM or GCM for instance) the sub-grid scale variability of microphysical, radiative and dynamical parameters can be computed and compared with those of models (WP 2.1).

Vertical structure of the flights



This flight plan consists in three legs of about 540km (45' minutes assuming the F20 speed is 200 ms^{-1}) aligned with the propagation direction of the MCS at three different altitude (7,9 and 12 km for instance, but in all cases well above the melting layer in order to avoid aircraft freezing problems), sampling the stratiform and cirriform regions of the MCS. These legs must overpass the ground based facility performing polarimetric measurements (Ronsard or Xport for instance) which will provide ice hydrometeor classifications to be validated. The remaining time of the mission will be used for taxi to the airport and ascending and descending trajectories in order to build vertical profiles of detailed microphysics properties with the in-situ probes.
This kind of flight plan will be particularly dedicated to the detailed vertical microphysics documentation, since the aircraft will sample three different altitudes where different ice particle habits are expected. This documentation is of particular interest to the improvement of rain products obtained from spaceborne microwave radiometers (WP4.3) and for validation of hydrometeor classification obtained with the ground-based polarimetric measurements (see WP2.1).
Such a flight plan will also give access to the temporal variability of microphysical, radiative and dynamical properties since the same vertical cross-section will be described three times. It is thus of particular interest for comparison with CRM simulation that will be performed with a detailed ice microphysics parametrisation in the framework of WP2.1.

Coordination with "MCS dynamics and environment" flights

As far as possible, it would be interesting to combine these "microphysical" filght, with those involving the airborne Doppler radar data onboard the US / NOAA-P3 aircraft. As a matter of fact, the derived three-dimensional wind and reflectivity fields will be used to compute vertical mass and humidity fluxes, and to determine the vertical profiles of entrainment / detrainment rates. We will particularly be interested in determining the magnitude and properties of detrainment in the upper troposphere, which is the source of humidity and hydrometeors forming the cirrus anvil clouds. Comparisons between these processes for MCSs of different size and intensity, and at diffrent stages of their evolution is important to understand the relations between deep convection and the production of upper level clouds.

Deliverables

During the first 12 months (June 04 – June 05)

- (June 04 – February 05) Development of the RALI instrument (see part 3.1 for details). Planning of the aircraft operation during the SOP-3 for addressing the objectives of WP1.2 and WP2.1 relevant to the water cycle, atmospheric dynamics and convection.
- (April 05 - June 05) Validation of RALI in the FR / F20 (test flights)

- Planning of the aircraft operation during the SOP-2 and SOP-3 for addressing the objectives of WP_1.2 and WP_2.1 (+ WP_2.4) relevant to the water cycle and atmospheric dynamics,

During the next 18 months (July 05 – Dec 06)

- (August 05 – December 05) First campaign for RALI : the CALIPSO/CloudSat Level 1 validation (scientific flights in France)
- Preparation of the airborne Doppler radar (US / NOAA-P3) and dropsonde (FR / F20) operation in Africa,
- Perform measurements during the SOP,
- Data processing and preliminary analyses,
- Delivery of processed data to the database.

Milestones

- T0+6 mo : Delivery of conclusions regarding
    - availability of aircraft for the in-situ measurements,
    - possibility to fly back in France between SOPs 2 and 3 to change FR / F20 Payload,
    - possibility of support / funding from the NASA and CNES in the framework of the CALIPSO/CloudSat validation effort during AMMA.
- T0+12 mo : Planning of the aircraft operation
- T0+12 mo : Validation of the 4-channel dropsonde system
- T0+15 mo : Validation of the RALI instrument
- T0+18 mo: First airborne campaign for RALI : CALIPSO/CloudSat validation (Level 1)
- T0+24 mo : Participation to SOP (measurement and aircraft operation)
- T0+30 mo : Delivery to data base

WORK CONTENT (1 YEAR)

The most important actions to be conducted in 2004 (and 2005) are :

- To confirm participation of US / NOAA-P3 in AMMA SOP & to interact with the US PIs ;
- To more precisely coordinate the scientific objectives and experimental design for both airborne and ground-based equipments, and for dynamic, precipitation and chemical aspects ;
- To validate the experimental design of aircraft operations using simulated data from numerical models (e.g. MesoNH, see WP_1.2) ;
- To conduct a test flight with the FR/F20 and the 4-channel dropsonde data system ;
- To start the necessary procedures to obtain flight and dropsounding authorizations;

A field campaign is planned in August-September 2005 with the Falcon equipped with RALI and part (or full) in-situ instruments. This campaign carried out from Creil will be devoted :

(i) To test and validate all the instrument chains on the new Falcon aircraft ;
(ii) To refine flight plans in order to optimize the combination of remote sensing measurements and in situ measurements performed in a same cloud ;
(iii) If possible, to perform flights over the SIRTA site to combine ground based remote observations and in situ data.

Instruments :

RASTA

- Calibration performed in February 2004 on the ground-based system which will be transferable to the airborne one. I
- New antenna system : A 5-beam system has been studied and its feasibility has been assessed. Its integration in the Falcon 20 is presently studied at INSU-DT. This new antenna system is particularly relezvant for our AMMA objectives since it provides the 3D wind field below the aircraft and the 2D wind field above at the same time.
- A new acquisition system with an improved sensitivity is also under development. The sensitivity of the radar should be around -28 dBZ@1 km.

LNG

A new high spectral resolution tri-wavelength lidar (LNG : Leandre New Generation) is under development. The high spectral resolution capability will allow better estimate of the backscatter coefficient and visible extinction.

RALI

- Testing the antenna system and the new acquisition of the radar (Feb 2005)
- Integrating RALI within the Falcon-20 and perform test flights (April-June 2005)
- Participation to the Level 1 validation of the CALIPSO/CloudSat mission (sometimes between August and December 2005)

IN-SITU SONDES

- Upgrade of the PMS 2D-P
- Certification of the CPI probe (DT/INSU)
- Validation of the new PXI Polar Nephelometer data acquisition system

Deliverables

- Fully prepared airborne equipment for SOPs
- Delivery and installation of airborne instrumentation
- Aircraft SOP contribution to scientific, experimental and logistical planning, coordination with other airborne platforms and ground-based sites

SUMMARY OF THE PLANNED AIRBORNE EXPERIMENTS DURING AMMA-SOPs

1 iop ATR-42 = 5 h 30 min = 5 h “ferry”+”science” + 30 min “safety margin” (max endurance = 6 h)

1 iop F-20 = 4 h 30 min = 4 h “ferry”+”science” + 30 min “safety margin” (max endurance = 5 h)

SOP	EXPERIMENT (PI)	REMARK	AIRCRAFT	nb of IOPs	FLIGHT HOURS
0	**SOP-0.F20** Remote sensing aerosol (PI : D. Tanré)	to be coordinated with UK / Bae-146	FR / F-20	9	***40.5 h***
0	**SOP-0.ATR** In situ aerosol (PI : D. Tanré)	to be coordinated with UK /Bae-146	FR / ATR-42	11	***60.5 h ****
* Two additional flights have been requested for cloud investigation by Schwarzenboeck et al.					
1 (2) #	**SOP-1(2).ATR. EW-AEROSOL** EW transect aerosol (PI : P. Formenti)	to be coordinated with Bae-146 and DE / F-20	FR / ATR-42	6	***33 h***
# L'étude des émissions d'aérosols terrigènes par les lignes de grain est à effectuer en priorité en SOP1, car les systèmes convectifs sont généralement non précipitants. Le cas échéant (e.g., absence de ligne de grain,difficultés logistiques, etc), ces vols pourront être reportés en SOP2					
1+2	**SOP-12.ATR. NS-AEROSOL** N-S / SW transect aerosol (PI : L. Gomes)	to be coordinated with Bae-146 and DE / F-20	FR / ATR-42	6	***33 h***
2	**SOP-2.ATR. CHEM-BUDGET** Gas phase measurements & chemistry budget (PI : P. Perros)	to be coordinated with BAe-146 and DE / F-20	FR / ATR-42	8	***44 h***
2	**SOP-2.F20. CHEM-BUDGET** Gas phase measurements & chemistry budget (PI : G. Ancellet/ P. Perros)	to be coordinated with Bae-146 and DE / F-20	FR / F-20	8	***36 h***
2	**SOP-2.F20. CHEM-TRANSPORT** Chemistry transport over W Africa (PI : K. Law)	to be coordinated with BAe-146 and DE / F-20	FR / F-20	3	***13.5 h***

1	**<u>SOP-1.ATR. NS-DYNAMICS</u>** Meridional transects (incl. N & S extents) + ITF flows (PI: F. Saïd)	to be coordinated with FR / F-20 and DE / F-20	FR / ATR-42	9	***49.5 h***
1	**<u>SOP-1.F20. NS-DYNAMICS</u>** Meridional transects (incl. N & S extents) (PI : C. Flamant)	to be coordinated with DE / F-20	FR / F-20	9	***40.5 h***
2	**<u>SOP-2.ATR. DYN-BUDGET</u>** Mesoscale flows (supersites) & MCS impact (PI : F. Saïd)	to be coordinated with FR / F-20 (MCS-ENV) and US / NOAA-P3 (if available)	FR / ATR-42	8	***44 h***
2	**<u>SOP-2.F20. MCS-ENV</u>** MCS environment (PI : F. Roux)	to be coordinated with US / NOAA-P3 (if available)	FR / F-20	10	***45 h***
3	**<u>SOP-3.F20. MCS-ENV</u>** MCS environment (PI : F. Roux)	to be coordinated with US / NOAA-P3 (if available)	FR / F-20	6	***27 h***
3	**<u>SOP-3.F20. MCS-ICE</u>** MCS ice microphysics (PI : D. Bouniol)	to be coordinated with DE / F-20	FR / F-20	6	***27 h***

« ESTIMATED » COST OF FRENCH AIRCRAFT OPERATIONS

FR / ATR-42 : 1 day = 3.0 k€, 1 flight hour = 0.55 k€

FR / F-20 : 1 day = 3.4 k€, 1 flight hour = 0.94 k€

1 dropsonde = 0.78 k€

1 return ticket = 0.85 k€, 1 day = 0.15 k€ (15 d = 3.5 k€, 25 d = 5.0 k€, 30 d = 5.5 k€)

PRE-SOP TESTS :

ITEM	*Travel and Stay*	*Aircraft fees*	*Flight hours*	*Dropsondes*
Test of dropsonding and 4-channel data system	2 p x 3 d (France) **(2 k€)**	1 d **(4 k€)**	4 h **(4 k€)**	6 ds **(5 k€)** 4-ch rcvr **(17 k€)**
Σ _dropsondes	***32 k€vol***			
ITEM	***Travel and Stay***	***Aircraft fees***	***Flight hours***	
Test of aerosol and gas instrumentation ATR42	8 p x 3 d (France) **(8 k€)**	2 d **(6 k€)**	10 h **(6 k€)**	***x***
Test of gas instrumentation F20	4 p x 3 d (France) **(4 k€)**	2 d **(8 k€)**	4 h **(4 k€)**	
Σtest_aerosols&chem.	***36 k€***			
Σ PRE-SOP tests	***68 k€***			

SOP-0 (Jan - 15 Feb 06**):**

ITEM	*Travel and stay*	*Aircraft fees*	*Flight hours*
SOP-0.ATR	12p x 30 d **(64 k€)**	30 d **(90 k€)**	60.5 h (11iop x 5.5h) **(34 k€)**
Σ SOP_0.ATR	***188 k€***		
SOP-0.F20	4p x 30 d **(22 k€)**	30 d **(102 k€)**	40.5 h (9iop x 4.5h) **(38 k€)**
Σ SOP_0.F20	***162 k€***		
ΣSOP-0	***350 k€***		

SOP-1 (1 - 30 June 06**):**

ITEM	*Travel and stay*	*Aircraft fees*	*Flight hours*
SOP-1(2).ATR.EW-AEROSOLS	3p x 30 d **(17 k€)**	(33/115.5) x 30d (90 k€) **(28 k€)**	33 h (6iop x 5.5h) **(18 k€)**
SOP-1+2.ATR.NS-AEROSOLS	8p x 30 d **(44 k€)**	(33/115.5) x 30d (90 k€) **(28 k€)**	33 h (6iop x 5.5h) **(18 k€)**
Σ SOP_12.ATR. AEROSOLS	***153 k€***		
SOP-1.ATR. NS-DYNAMICS	3p x 30 d **(17 k€)**	(49.5/115.5) x 30d (90 k€) **(39 k€)**	49.5 h (9iop x 5h) **(27 k€)**
Σ SOP-1.ATR. NS-DYNAMICS	***83 k€***		
SOP-1.F20. NS-DYNAMICS	3p x 30 d **(17 k€)**	30 d **(102 k€)**	40.5 h (9iop x 4.5h) **(38 k€)**
	DROPSONDES : (9 iop x 10 ds) **(70 k€)**		
Σ SOP-1.F20. NS-DYNAMICS	***227 k€***		
Σ SOP-1	***463 k€***		

SOP-2 (July - 14 August 06**):**

ITEM	*Travel and stay*	*Aircraft fees*	*Flight hours*
SOP-2.ATR. CHEM-BUDGET	2p x 30d **(11 k€)**	(44/88) x 45d (135 k€) **(67 k€)**	44 h (8iop x 5.5h) **(24 k€)**
Σ SOP-2.ATR. CHEM-BUDGET	***102 k€***		
SOP-2. F20. CHEM-BUDGET	6p x 40d **(41 k€)**	(49.5/94.5) x 45d (153 k€) **(81 k€)**	36 h (8 iop x 4.5h) **(34 k€)**
SOP-2. F20. CHEM-TRANSPORT			13.5 h (3 iop x 4.5h) **(12 k€)**
Σ SOP-2.F20. CHEM	***168 k€***		
SOP-2. A. DYN-BUDGET	2 x 3p x 25d **(30 k€)**	(44/88) x 45d (135 k€) **(68 k€)**	44 h (8iop x 5.5h) **(24 k€)**
Σ SOP_2.ATR. DYN-BUDGET	***122 k€***		
SOP-2.F20. MCS-ENV	2 x 3p x 25d **(20 k€)**	(45/94.5) x 45d (153 k€) **(72 k€)**	45 h (10iop x 4.5h) **(42 k€)**
	DROPSONDES : (10 iop x 20 ds) **(154 k€)**		
Σ SOP-2.F20. MCS-ENV	***288 k€***		
Σ SOP-2	***680 k€***		

SOP-3 (-31 August 06**):**

ITEM	*Travel and stay*	*Aircraft fees*	*Flight hours*
SOP-3.F20. MCS-ENV	3p x 15 d **(11 k€)**	(27/54) x 15d (51 k€) **(26 k€)**	27 h (6iop x 4.5h) **(25 k€)**
	DROPSONDES : (6 iop x 20 ds) **(94 k€)**		
Σ SOP-3.F20. MCS-ENV	***156 k€***		
SOP-3.F20. MCS-ICE	3p x 15 d **(11 k€)**	(27/54) x 15d (51 k€) **(25 k€)**	27 h (6iop x 4.5h) **(25 k€)**
Σ SOP-3.F20. MCS-ICE	***61 k€***		
Σ SOP-3	***217 k€***		

+ Cost of French aircraft operations (from SAFIRE) :

- return flights, travel and stay expenses for technical aircraft staff, miscellaneous : **250 k€**
- local logistics : **50 k€**
- travel and stay expenses for technical ground-based staff during AMMA-SOP : **37 k€**

TOTAL **337 k€**

+ French inclusive contribution to NOAA-P3 operations (to be confirmed) :

- participation to flight hours during SOP-2+3 **200 k€**
- travel and stay expenses for (2 x 3p x 25d) : **30 k€**

TOTAL **230 k€**

TOTAL SOP-0 :	350 k€
TOTAL SOP-1 :	463 k€
TOTAL SOP-2 :	680 k€
TOTAL SOP-3 :	217 k€
TOTAL PRE-SOP :	68 k€
TOTAL MISC. FR A/C :	337 k€
TOTAL US / NOAA-P3 :	230 k€
TOTAL :	**2345 k€**
TOTAL FR / ATR :	648 k€
TOTAL FR / F20 :	744 k€
TOTAL dropsondes :	318 k€
TOTAL PRE-SOP :	68k€
TOTAL MISC. FR A/C :	337 k€
TOTAL US / NOAA-P3 :	230 k€
TOTAL :	**2345 k€**

Amount requested from EU AMMA / IP for FR / F20 operations and dropsondes :
***439.20 k€** (41% of [744 + 318 = 1062] k€)*

France / SAFIRE / FA-20 F-GBTM

S.HOX_FF20	Mass spectrometer with chemical ionisation	SAFIRE-FA20	RO2, HO2 and OH in situ	CNRS IPSL	A. Kukui alexandre.kukui@aero.jussieu.fr	2006
S.Mona_FF20	Nitrogen oxides analyser	SAFIRE-FA20	NO, NO2 and NOy in situ	LISA	P. Perros perros@lisa.univ-paris12.fr	2006
S.COV_FF20	Microadsorbent tubes and ground analysis with GC--MS	SAFIRE-FA20	VOC	LISA	P. Perros perros@lisa.univ-paris12.fr	2006
S.COVO_FF20	Oxygenated VOC sampling and ground analysis with GC--MS	SAFIRE-FA20	Oxygenated VOC	LISA	P. Perros perros@lisa.univ-paris12.fr	2006
S.RALI_FF20	95 GHz radar / aerosol Lidar	SAFIRE-FA20	Cloud physical proporties	INSU-DT	N. Grand noel.grand@dt.insu.cnrs.fr	2006
S.Mozart_FF20	UV-O3 and IR-CO instrument	SAFIRE-FA20	O3 and CO in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LA_FF20	Lyman-α fluorescence and dew point	SAFIRE-FA20	Water Vapour H_2O	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.GPS_FF20	INS, GPS	SAFIRE-FA20	Position, winds, u,v,w	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.5PTP_FF20	5-port turbulence probe	SAFIRE-FA20	Turbulence	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PRT_FF20	Rosemount PRT	SAFIRE-FA20	Temperature T	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.Drop_FF20	AVAPS dropsondes	SAFIRE-FA20	Vertical profiles of dynamical variables	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.HUR_FF20	Aerodata humidity sensor	SAFIRE-FA20	Relative Humidity	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.BBR_FF20	Pygreometers and Pyranometers	SAFIRE-FA20	Broadband radiation	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.JNO2_FF20	Photometer	SAFIRE-FA20	NO_2 photolysis $j(NO_2)$	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PMS_FF20	Size particle / rain drop distribution	SAFIRE-FA20	300 to 3 000 nm PCASP PMS: 1DC-OAPX, 1DP-OAPY, 2DC,	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LEANDRE_FF20	Aerosol profiles	SAFIRE-FA20	Lidar	IPSL	J. Pelon Jacques.Pelon@aero.jussieu.fr	2006

S.Dirac_FF20	Brightness temperatures	SAFIRE-FA20	IR radiometer	IPSL	J. Pelon Jacques.Pelon@aero.jussieu.fr	2006
OSIRIS_FF20	Polarization and directionnaltiy of earth reflectances from 440 to 2200nm	SAFIRE-FA20	Aerosol Optical thickness, Size Distribution	LOA	J. F. Léon	2006
MINIMIR+MICROPOL	Polarization and directionnaltiy of earth reflectances from 440 to 2200nm	SAFIRE-FA20	Aerosol Optical thickness, Size Distribution	LOA	J. F. Léon	2006
CLIMAT	Multichannel thermal infrared radiometer.	SAFIRE-FA20	Brightness temperatures	LOA	G. Brogniez	2006

France / SAFIRE / ATR-42 F-WQNI

S.SPR_ATR42	Rosemount,Thales Avionic	SAFIRE-ATR42	Static pressure	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PRT_ATR42	Rosemount PRT	SAFIRE-ATR42	Temperature T	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.DP_ATR42	Buck Research dew point sensor	SAFIRE-ATR42	Dew point	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LA_ATR42	AIR and ERCLyman-α	SAFIRE-ATR42	Water Vapour H_2O	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LWC_ATR42	King Probe, Gerber Probe, JW	SAFIRE-ATR42	Liquid water content	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.GPS_ATR42	INS, GPS	SAFIRE-ATR42	Position, winds, u,v,w	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.5PTP_ATR42	5-port turbulence nose	SAFIRE-ATR42	Turbulence	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.HEIGHT_ATR42	Thales Avionic radioaltimetre	SAFIRE-ATR42	Height above ground	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.NOx_ATR42	Chimiluminescence NOx instrument	SAFIRE-ATR42	NO, NO2 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.CO_ATR42	IR-CO instrument	SAFIRE-ATR42	CO in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.O3_ATR42	UV-O3 instrument	SAFIRE-ATR42	O3 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.JNO2_ATR42	Photometer	SAFIRE-ATR42	NO_2 photolysis $j(NO_2)$	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.CPC_ATR42	TSI condensation particle counters	SAFIRE-ATR42	Particle number concentration > 10 nm	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PCASP_ATR42	Externally sampling PCASP	SAFIRE-ATR42	Size distribution (0.2-30 um)	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.BBR_ATR42	Pygreometers and Pyranometers	SAFIRE-ATR42	Broadband radiation	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PMS_ATR42	Size particle / rain drop distribution	SAFIRE-ATR42	PMS: 1DC-OAPX, 1DP-OAPY, 2DC, FSSP	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.AVIRAD_ATR42	AVIRAD particle inlet	SAFIRE-ATR42	Coarse particle inlet	LISA/LSCE	formenti@lisa.univ-paris12.fr	2006
S.GRIMM_ATR42	Optical sizer GRIMM	SAFIRE-ATR42	Size distribution (0.2-30 um)	LISA	formenti@lisa.univ-paris12.fr	2006

S.AETH_ATR42	7-□ aethalometer	SAFIRE-ATR42	Particle soot, black carbon	LISA	formenti@lisa.univ-paris12.fr	2006
S.Neph_ATR42	3-□ Nephelometer	SAFIRE-ATR42	Spectral Scattering	LISA	formenti@lisa.univ-paris12.fr	2006
S.Filt_ATR42	filters for individual particle analysis	SAFIRE-ATR42	Particle shape	LISA	formenti@lisa.univ-paris12.fr	2006
S.DKT_ATR42	4-stage impactors	SAFIRE-ATR42	Aerosol composition	LISA	formenti@lisa.univ-paris12.fr	2006
S.COV_ATR42	Microadsorbent tubes and ground analysis with GC--MS	SAFIRE-ATR42	VOC	LISA	perros@lisa.univ-paris12.fr	2006
S.COVO_ATR42	Oxygenated VOC sampling and ground analysis with GC--MS	SAFIRE-ATR42	Oxygenated VOC	LISA	perros@lisa.univ-paris12.fr	2006
S.PEROX_ATR42	Peroxide Fluorometer	SAFIRE-ATR42	Speciated peroxides (inorg/organic)	LISA	perros@lisa.univ-paris12.fr	2006
S.PAN_ATR42	PAN-GC	SAFIRE-ATR42	Peroxyacetylnitrate	LISA	perros@lisa.univ-paris12.fr	2006
S.PMS_ATR42	PMS: 1DC-OAPX, 1DP-OAPY, 2DC, FSSP	SAFIRE-ATR42	Size particle / rain drop distribution	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.UCPC_ATR42	Ultrafine CPC	SAFIRE-ATR42	Particle number concentration > 3nm	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.CPC_ATR42	Multi-channel CPCs	SAFIRE-ATR42	Size distribution > 10nm	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.CCN_ATR42	CCN counter	SAFIRE-ATR42	CCN	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.FFSSP_ATR42	Fast FSSP	SAFIRE-ATR42	Cloud droplet spectrum	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.XPRO_ATR42	X-Probe	SAFIRE-ATR42	Aerosol and droplet size distribution (0.5-50 µm)	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.FIL_ATR42	filters for sub and supermicron particle collection	SAFIRE-ATR42	Ions, trace, BC/OC	LA	V. Pont ponv@aero.obs-mip.fr	2006
S.DMA_ATR42	DMPS	SAFIRE-ATR42	Size distribution of Aitken and accumulation mode particles (20-1000 nm)	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr	2006
S.PCASP_ATR42	PCASPX	SAFIRE-ATR42	Size distribution 0.3-10 µm	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr	2006
S.THERMO_ATR42	Thermodenuder	SAFIRE-ATR42	Volatility analysis of particles	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr	2006

S.CVI_VEINE_ATR42	CVI air inlet	SAFIRE-ATR42	Extraction of non-volatile as well as volatile species from individual hydrometeors	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_DMPS_ATR42	DMPS for CVI	SAFIRE-ATR42	Interstitial & Residual particle size spectra (<1µm)	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_LAS_ATR42	LAS-200 for CVI	SAFIRE-ATR42	Interstitial & Residual particle size spectra (0.1-10µm)	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_SPAR_ATR42	SEM/TEM filters for CVI	SAFIRE-ATR42	Single particle analysis of interstitial & residual particles	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_HYGR_ATR42	Lyman-□ Hygrometer	SAFIRE-ATR42	Cloud LWC / IWC	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_CHEM_ATR42	Chemical analysis (filters for inorganic/organic component analysis	SAFIRE-ATR42	Interstitial & Residual particle chemistry (inorganic & organic material)	LaMP	A.A. A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.CVI_PSAP_ATR42	Particle Soot Absorption Photometer	SAFIRE-ATR42	Mass of residual & interstitial particle absorbing material using specific absorption coefficient	LaMP	A. Schwarzenboeck A.Schwarzenboeck@opgc.univ-bpclermont.fr	2006
S.LAUVA_ATR42	UV lidar	SAFIRE-ATR42	Aerosol vertical profile	LSCE	P. Chazette pch@lsce.saclay.cea.fr	2006
S.PLASMA_ATR42	Tracking sunphotometer	SAFIRE-ATR42	Aerosol optical depth	LOA	D. Tanré Didier.Tanre@univ-lille1.fr	2006