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THE EGEE3/AMMA EXPERIMENT

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The EGEE experiment is the oceanographic component of the AMMA program. It focuses on the oceanic circulation and on air-sea interactions in the Gulf of Guinea. Part of this program, EGEE3 will take place in May-July 2006. The main scientific objectives are to document: (1) the seasonal and inter-annual variability of the circulation through repeated trans-equatorial sections with hydrological and current measurements; (2) the processes leading to the strong boreal summer cooling of sea surface temperature along the Equator and at the coast and its link with the African Monsoon. The role of sea surface fluxes will be investigated through continuous measurements of surface fluxes; radio-soundings twice a day and oceanic mixed layer properties with drifting buoys. This data set will be used to document the monsoon flux over the Gulf of Guinae, to derive bulk flux parameterizations, produce gridded fluxes, model and determine oceanic and atmospheric mixed layer processes, validate operationnal oceanic/atmospheric models, and also to test new methods for reconstructing gridded fluxes form satellite.

Le programme EGEE est la partie océanographique de AMMA. Il vise à documenter la circulation océanique et les interactions océan-atmosphère dans le Golfe de Guinée. La campagne EGEE3 fait suite à EGEE1 et EGEE2 et aura lieu entre mai et juillet 2006, lors des SOP1 et SOP2. Ses objectifs scientifiques sont: (1) l'étude de la variabilité saisonnière de la circulation océanique réalisée grâce à des sections trans-équatoriales déjà réalisées lors de campagnes antérieures à l'aide de mesures hydrologiques et courantométriques; (2) l'étude des processus de surface conduisant à la forte évolution des températures de surface de la mer, son lien et son rôle sur la Mousson Africaine. Des mesures continues de paramètres météo-océaniques et de flux seront réalisées, ainsi que des radio-sondages. Des bouées donneront des renseignements sur la couche de mélange océanique. Toutes ces données permettront de documenter le flux de mousson sur le Golfe de Guinée, de reconstituer et de valider des champs de flux grillés à fine échelle; de modéliser l'océan superficiel; de déterminer les processus océaniques de sub-surface ainsi que dans la couche limite atmosphérique; de valider des modèles opérationnels; enfin de tester des méthodes de restitution de flux par satellite.

Scientific objectives

The Equatorial Atlantic Basin is a region of important climatic sea surface temperature (SST) variability. This variability is highly correlated with land rainfall anomalies, on the South American continent (Nordeste in Brazil) and on the African continent, as well as with the position and extension of the Monsoon system (Vizy and Cook, 2001).

One important question for the monsoon problem is the marked seasonal cycle in the Gulf of Guinea (GG), associated with the development of a coastal up-welling and the development of the "cold tongue", a SST cooling which appears in boreal summer, starting in the South-Eastern part of the basin and rapidly reaching the middle of the Equatorial basin. This system, largely influenced by the establishment of the south-westerly winds of the monsoon, tends to establish a large meridian SST gradient in the GG.

The variation of the SST is also largely dependent of the complex current system. In the northern part of the GG, the circulation is dominated by the Eastward Guinea Current, which is sometimes considered as the extension of the North Equatorial Counter Current in boreal summer. Like in the Pacific, the circulation is characterised by the eastward Equatorial Undercurrent underlying the westward South Equatorial Current. However, the circulation in the eastern part of the GG is complex, highly variable and not well documented (Bourlès *et al.*, 2002; 2003).

Consequently, the processes that modulate the SST in this part of the Atlantic are largely unknown (Foltz *et al.*, 2003). SST is influenced by the surface fluxes related to the wind enhancement associated to the Monsoon, especially through the latent heat, but also depends on the upper circulation due to advection. The contribution of these processes and also of vertical advection associated to the development of up-welling and of the cold tongue is thus to be determined.

In addition, the salinity field in the eastern part of the GG is dominated by a large freshening, due both to large precipitation rates and river runoff, principally due the presence of the Congo and Niger rivers. This freshening is able to modify the stability in the oceanic upper layers and the vertical mixing in the mixed layer, thus influencing the SST evolution.

In order to illustrate the annual and latitudinal variation of the SST, Figure 1 shows these variations deduced from the last 10 years Reynold SSTs. SSTs were averaged over a band 8 degrees of longitude from 4°W to 4°E. In April the SST is at a maximum at all latitudes, with a North to South gradient of 2°C over 14° of latitude. After the monsoon jump at the end of June, an intense cooling is observed until September with an increase of the latitudinal gradient which reaches 3° to 4°C over 14° of latitude. From October to April, the SST increases regularly with an excess of heating in the southern part of the basin in order to re-establish the initial latitudinal gradient.

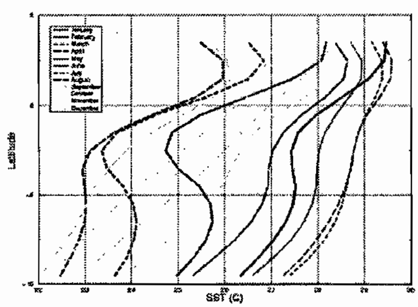

Figure 1: latitudinal and monthly variations of 10 years Reynold's SSTs averaged over a band 4°W-4°E over the GG

The different scientific questions to be addressed during the SOP and LOP concerning the air-sea interactions are:

- what is the role of the surface fluxes in the evolution of the oceanic upper layers and what is the role of the monsoon in modifying these fluxes?
- what is the oceanic response to the monsoon (Ekman transport, development of up-welling), and how does this response affect the evolution of the SST, mean mixed layer temperature/salinity and mixed layer depth?
- what are the transfers through the mixed layer base, what is the importance of the vertical velocity, of the vertical advection, specifically in the up-welling regions; in which part of the Equatorial Basin does the vertical velocity play its major role?
- what is the effect of SST, especially of the SST fronts associated with the cold tongue and coastal up-welling on the atmospheric mixed layer and how does this mixed layer influence the monsoon flow?
- what is the role of salinity, especially its freshening in the eastern part of the GG, the role of precipitation/runoff on the stability of the mixed layer and its influence on the temperature profiles?
- do the parameterizations of the turbulent heat fluxes or reconstruction of the turbulent heat fluxes from satellites allow us to reconstruct basin scale flux fields and what is their ability in forcing oceanic mixed layer models?
- do NWP models succeed in producing heat, freshwater and momentum fluxes? Do oceanic models (MERCATOR, CLIPPER) succeed in modelling the top layers, the characteristics of the mixed layer and the current systems along the Equator and in the GG?

The experimental strategy

The EGEE program consists of different campaigns at sea, where in-situ data will be collected during the specific periods defined in AMMA. In order to complete the EOP, two campaigns were realised in 2005 (EGEE1 and EGEE2, Bourlès *et al.*, 2005) and two are programmed for 2006 (EGEE3) and 2007. During these three years, great attention will be given to document inter-annual variability (currents, development of the cold tongue and of up-welling) during specific periods of the year when these oceanic conditions are present.

During the SOP, a larger component of the program will be given to air-sea interactions. EGEE3 will thus be largely dedicated to the upper ocean and to the coupling with the marine atmospheric boundary layer. Outside the intense observation periods, operational in-situ data arrays will be used: the PIRATA buoy array and a specially equipped met-station installed by IRD on the Island of São Tomé, as well as numerical model output and satellite products.

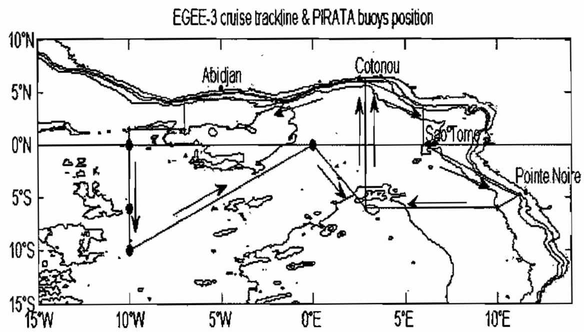

Figure 2: Ship trajectory planned during EGEE3 and the position of the PIRATA buoys

The EGEE3 campaign will thus take place between the end of May 2005 and the beginning of July. Three main requirements were taken into account for the experimental strategy: (1) the two legs were programmed in order to take place before the monsoon jump (which takes place climatologically around the end of June) and the second one just after: (2) during this period, the development of the cold tongue across the Equatorial Basin and the establishment of the northern coastal up-welling will occur and will be documented through specific North to South cross sections; (3) the section at 3°E is programmed to be covered twice, at the end of each legs so that coupled ship and aircraft measurements can be achieved at the same time; (4) the maintenance of the PIRATA buoys at 3°E, 0°W and 10°W; the deployment of a new PIRATA buoy at 8°E; 6°S (if funded) and a fixed point in front of the island of São Tomé where a met-station has been specially installed for AMMA/EGEE in order to compare ship and on-land data series.

Figure 2 portrays the 2 legs and the direction along their trajectory that will be covered by the ship R/V ATALANTE during EGEE3. The western part of the GG will be covered from 26 May to 15 June 2006 and the eastern part from 17 June to 6 July 2006. Systematic CTD transects will be carried out that will be associated to the in-situ data arrays, as well as additional XBT measurements between the CTD stations. The Equatorial cross sections will complement similar cross sections that were covered during previous experiments: EQUALANT99 (Gouriou *et al.*, 2001), EQUALANT 2000 (Bourlès *et al.*, 2002) and the EGEE1 and EGEE2 cruises (Bourlès *et al.*, 2005).

The following data will be collected according to the air-sea interaction program:

- continuous atmospheric measurements with an instrumented mast located on the foredeck of the ship; this mast has been used for several experiments at sea for the past 10 years by the French community (cf. the ALBATROS database (Weill *et al.*, 2003; address: http://dataserv.cetp.ipsl.fr/) developed in the framework of the AUTOFLUX project, a European project for the measurement and parameterization of turbulent fluxes over sea (Larsen *et al.*, 2003). It can provide air temperature, humidity, atmospheric pressure, horizontal velocity with corrections for airflow distortion due to the ship (Brut *et al.*, 2005), radiative fluxes (incoming solar radiation and incoming infra-red, mounted with a hook's coupling system),
- continuous SST, salinity and currents velocity measurements; an U.S. invited experiment will be devoted to the skin temperature with the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) (Minnett et al., 2001),
- continuous measurements of turbulence with the instrumented mast in order to determine the turbulent fluxes (latent heat, sensible heat, wind stress) by applying the inertio-dissipative method, the eddy correlation method and the bulk method (Weill *et al.*, 2003); a licor 7500 analyzer will also be tested in order to estimate latent heat fluxes by a fourth method,
- specific rain gauge and measurements of rain temperature will be installed onboard by the CETP (Paris) to determine the influence of top layer cooling associated with rain,
- drifting buoys (MARISONDE) will be launched; these buoys have a thermistance chain and will be used to document the mixed layer / upper thermocline along their trajectories,
- deep drifting PROVOR profilers will be deployed; these profilers provide T/S vertical profiles from the surface down to 2000m every 10 days, in a ARGO program configuration. With these data, the surface fluxes can be estimated as a residue of the heat budget measured between consecutive profiles and can be a valuated method to evaluate errors of gridded satellite and model flux fields,
- Surface Velocity Profilers (SVP) will be deployed; these surface buoys provide daily their position and the SST,
- systematic radio-soundings will be launched at synoptic hours in order to complete the ground station array over the African continent and to be assimilated in real time by the NWP models; improved atmospheric fields to retrieve gridded fluxes over the whole GG are thus expected,

- about 100 temperature, salinity, current and oxygen profiles will be carried out during hydrological stations; some profiles will be repeated during a few "long duration –24 to 36h- stations".

The EGEE3 cruises will be coordinated with 2 other experiments: the German R/V METEOR and US Ron BROWN which is a unique opportunity for covering the Equator Basin during the SOP1 and SOP2. The R/V METEOR cruises (campaigns M68/2 and M68/3) are planed in the framework of TACE (CLIVAR)/AMMA/SOLAS for the period June to August 2006 by the IFM/GEOMAR in Kiel (Chief scientist: Peter Brandt). It will include, besides hydrographic measurements, continuous measurements of SST and SSS, air temperature, humidity, pressure wind and precipitation, global radiation and incoming longwave radiation. Radiosoundings will also be launched twice a day. The ship will settle the eastern Equatorial Basin, from 35°W to 10°W with special deployment of moorings along 23°W in order to quantify advection and vertical mixing in the oceanic surface layers.

The R/V Ron BROWN is also participating in the AMMA deployment in the framework of the TACE and SOLAS programs. The campaign will be held from end May to mid-July for 44 days along the 23°W from 6°N to 6°S. Similar flux measurements as onboard the R/V ATALANTE are scheduled so as radiosoundings and hydrographic profiles along the section.

Complementary data

During the EGEE3/AMMA experiment, satellite data will be used as a source of data for covering the GG, and as comparison with in-situ data, in order to gauge the quality of the satellite algorithms. The experiment will be an opportunity to collect data to be compared against satellite retrievals of SST, radiative fluxes and wind. Note that radiative fluxes at sea are not collected systematically and operationally as is done on land stations and there is a crucial need for this kind of data at sea (Marsouin *et al.*, 2005).

Satellite data will be also used extensively to provide data for computing gridded surface flux fields at a fine temporal and spatial scale. Different data centre (*i.e.* the OSI-SAF) will thus be an important source of data for this program. Expected data concerns: SST at a temporal scale of 1hr or 3hr in order to reconstruct the diurnal cycle, winds, radiative solar and infrared fluxes.

From these fields, specific net heat freshwater and movement flux fields will be derived by using different methods: synthesis approach (Caniaux *et al.*, 2005) or from satellite retrievals (Bourras *et al.*, 2003; Bentamy *et al.*, 2005). With these fields, a hierarchy of oceanic models (see the review by Giordani *et al.*, 2005) can be forced and run to simulate the development of the cold tongue and coastal upwelling, evaluate the processes at play during specific period in the GG. Flux data sets along the ship trajectory or along the MARISONDE buoy trajectories will be used to validate NWP fluxes, satellite retrievals and evaluate the capacity of models to simulate mixed layer processes.

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Convective wind system with aerosols, named “haboob”, Hombori in Mali, West Africa.