Flotte océanographique française

# PROPOSITION DE CAMPAGNE A LA MER

## Appel d'offre campagnes hauturières 2020

**Nom de la campagne :** EUREC4A_OA

**Nom du chef de mission principal :** SPEICH Sabrina

Ifremer CNRS IPEV IRD Institut de recherche pour le développement

## Sommaire

# I- Informations préliminaires

| | |
|---|---|
| **Nom complet de la campagne :** | EUREC4A Ocean Atmosphere interactions |
| **Acronyme de la campagne :** | EUREC4A_OA |
| **Appel d'offres :** | Appel d'offre campagnes hauturières 2020 |

**Responsables de campagne (chefs de mission):**


| | |
|---|---|
| **Nom - Prénom :** | SPEICH Sabrina |
| **Organisme :** | LABORATOIRE DE MÉTÉOROLOGIE DYNAMIQUE - UMR 8539 |
| **Adresse :** | 24, rue L'homond |
| **Tél :** | 01 44 32 22 48 |
| **E-Mail :** | speich@lmd.ens.fr |

| | |
|---|---|
| **Nom - Prénom :** | REVERDIN Gilles |
| **Organisme :** | LABORATOIRE D'OCEANOGRAPHIE ET DU CLIMAT- UMR 7159 (LOCEAN) |
| **Adresse :** | UMR 7159 CNRS / IRD / Université Pierre et Marie Curie/MNHN |
| **Tél :** | (33) 1 44 27 23 42 |
| **E-Mail :** | Gilles.Reverdin@locean-ipsl.upmc.fr |

| | |
|---|---|
| **Nom - Prénom :** | BELLENGER Hugo |
| **Organisme :** | LMD LABORATOIRE DE METEOROLOGIE DYNAMIQUE - PALAISEAU |
| **Adresse :** | Ecole Polytechnique |
| **Tél :** | 0144277352 |
| **E-Mail :** | hugo.bellenger@lmd.jussieu.fr |


**Proposition d'experts :**
**Refus d'experts :**

**Rédacteurs :**

# II- Informations générales

## II-1 Définition

| | |
|---|---|
| **Année demandée :** | 2020 |
| **Type de la campagne :** | Recherche scientifique hauturière |
| **Thème de la campagne :** | étude de la dynamique océanique de méso et sub-méso échelles, de leurs rôles dans l'interaction océan-atmosphère pour tenter de comprendre leurs impacts sur la dynamique de la couche limite atmosphérique et sur les caractéristiques de la convection |

**Préambule :**

La campagne EUREC4A-OA constitue la composante interactions océan-atmosphère Française d'un très vaste et ambitieux projet internationale, EURC4A/ATOMIC/EUREC4++ focalisant sur l'étude de la dynamique océanique de méso et sub-méso échelles, de leurs rôles dans l'interaction océan-atmosphère pour tenter de comprendre leurs impacts sur la dynamique de la couche limite atmosphérique et sur les caractéristiques de la convection peu profonde. La période est fixée par la mise en oeuvre d'avions

**Disciplines étudiées :**

| Code | Discipline |
|---|---|
| ATMOS | ATMOSPHERE |
| CHIMIE | CHIMIE OCEANIQUE |
| METEO | METEOROLOGIE |
| PHYS | OCEANOGRAPHIE PHYSIQUE |

**S'agit t-il d'une première demande ?** Oui

## II-2 Positions

| | |
|---|---|
| **Port de départ (Mobilisation) :** | Bridgetown |
| **Port d'arrivée (Démobilisation) :** | Bridgetown |
| **Détails Zone géographique :** | Océan Atlantique Tropical Nord Ouest |

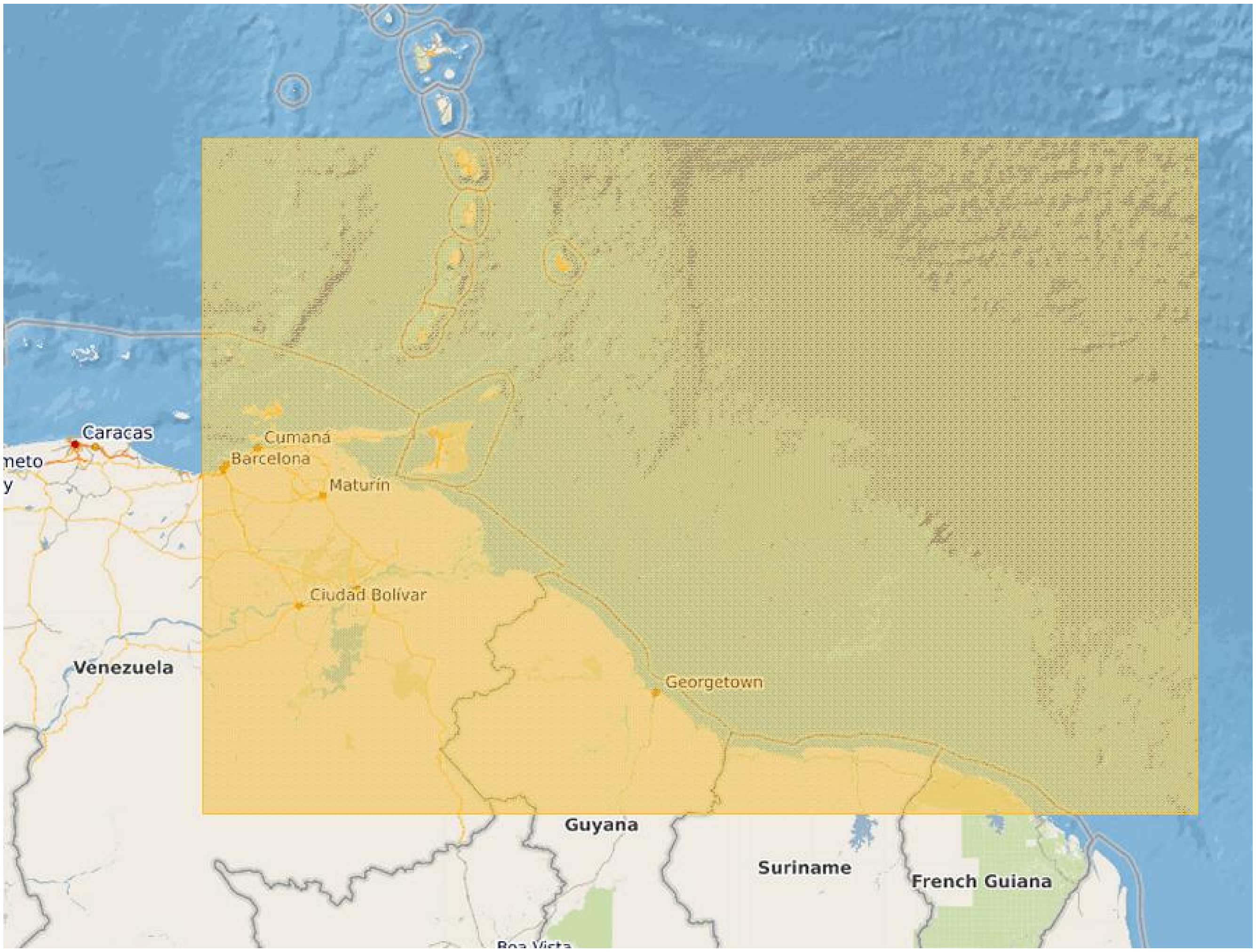
**Zones géographiques :**

| Code | Zone |
|---|---|
| SVX00005 | Océan Atlantique |
| 1 | Océan Atlantique Nord |

**Limites géographiques :**

| Nord | Sud | Est | Ouest |
|---|---|---|---|
| 15 | 5 | -50 | -65 |

**Mission uniquement en eaux internationales ou françaises?** Oui




## II-3 Dates

| | |
|---|---|
| **Date de début de campagne :** | 2020-01-20 |
| **Date de fin de campagne :** | 2020-02-20 |
| **Justification date :** | La campagne EUREC4A-OA est programmée pour avoir lieu en même temps que les vols des avions pour EUREC4A et la présence concomitante des deux navires Allemands (M.S. Merian et Meteor) ainsi que le navire de la NOAA Ron Brown. |
| **Temps moyen de travail à la mer par 24 heures :** | 24 |
| **Temps total de transit (en jours et heures) :** | 5 jours |
| **Durée :** | 31 |

## II-4 Types de travaux

**Type de travaux :**

Stations CTDs/rosette, MVP, VMP, Ballons radiosondes, gliders, flotteurs Argo, deploiement de OCARINA/PICCOLO, mesures underway variées océan-atmosphère

| | |
|---|---|
| **Nécessité d'une campagne de récupération ?** | Non |
| **Nécessité Soutien Gestionnaire Technique pour le traitement des acquisitions ?** | Non |

## II-5 Série de campagnes

**Série à laquelle appartient la campagne**

**DOI**

**Responsables**

**Objectifs :**

## II-6 Programmes rattachés

**Programme(s) dans lesquel(s) la campagne s'inscrit**

**Autres projets de rattachement :** LEFE IMAGO, ANR, ERC, CLIVAR, WCRP

# IV- Résumé de la mission

**Mots-clés (FR)**

***Interactions océan-atmosphère,mésoéchelle océanique,sousmésoéchelle océanique,convection atmosphérique,turbulence,couches limites***

**Résumé de la mission (FR)**

Les tourbillons océaniques à méso-échelle créent des modes d'interaction air-mer spécifiques qui peuvent avoir un effet intégral sur l'atmosphère et la dynamique océanique à grande échelle. Les progrès récents dans l'état de l'art de ces processus ont été principalement obtenus grâce aux efforts de modélisation, mais il n'existe que très peu d'études observationnelles, et elles sont toutes situées dans les régions extra-tropicales. L'ajout d'une étude expérimentale dédiée aux interactions à la mésoéchelle océanique à la campagne aeroportée EUREC$^4$A permettra d'améliorer les objectifs et le succès de l'ensemble du programme en établissant une contrainte océanique locale à l'évolution atmosphérique (comme indiqué dans la conception globale de EUREC$^4$A: Bony et al. 2017). La variabilité temporelle sur une zone d'étude à méso-échelle fixe (500 km x 500 km) permet d'échantillonner différents états atmosphériques, sur les échelles de temps de EUREC$^4$A. La composante océanographique qui s'ajoute à EUREC$^4$A consiste en quatre navires échantillonnant l'océan à méso-échelle et les échanges air-mer à quatre bords différents de la région ciblée par EUREC$^4$A. Cela permettra un échantillonnage spatial étendu qui est nécessaire pour caractériser la variabilité de l'océan et recueillir suffisamment d'observations air-mer sur différentes zones pour évaluer avec précision les processus et les impacts impliqués.

L'Atlantique tropical occidental est un laboratoire idéal pour l'étude proposée. Elle abrite une riche variabilité océanique à mésoéchelle (et à sousmésoéchelle) dans une atmosphère caractérisée par un régime d'alizés assez stable. Dans cette région, les tourbillons océaniques ont un diamètre de 200 à 300 km et une durée de vie de plusieurs mois à des années. En particulier, au sud de la Barbade, on trouve couramment des tourbillons anticycloniqus très énergiques et de longue durée provenant du Courant du Brésil Nord. Ces tourbillons sont essentiels pour le transport vers le l'Atlantique Nord des masses d'eau provenant de l'Atlantique Sud et qui constituent un élement essentiel de l'*Atlantique Meridional Overturning Circulation* (AMOC). De plus, des études préliminaires basées sur des observations satellitaires suggèrent que ces tourbillons jouent un rôle crucial dans les interactions air-mer et dans l'atmosphère. C'est spécifiquement dans cette région spécifique de l'Atlantique Tropical Nord et sur ces tourbillons de mésoéchelle que se focalisera la campagne EUREC$^4$A-OA.

**Mots-clés (EN)**

***ocean-atmosphere interactions,ocean mesoscale,ocean submesoscale,atmospheric convection,turbulence,boundary layers***

**Résumé de la mission (EN)**

Ocean mesoscale eddies create specific air-sea interaction patterns that can have an integral effect on the large scale atmosphere and ocean dynamics. Recent advances in the state of the art of these processes has been predominately obtained from modeling efforts, but only very few observational studies exist, and there are all located in the extra-tropics. Adding a dedicated ocean mesoscale eddy air-sea interaction experiment to the EUREC$^4$A campaign will enhance the objectives and success of the whole program as it sets a local, oceanic constrain to the atmospheric evolution (as been outlined in the overall EUREC$^4$A design; Bony et al. 2017). Temporal variability over a fixed mesoscale (500 km x500 km) study area allows for sampling varying atmospheric states, on the time-scales of the EUREC$^4$A field study. The oceanographic component that add on EUREC$^4$A consists of four ships sampling the mesoscale ocean and air-sea exchanges at four different edges of the airborne field

experiment. This will enable the extended spatial sampling required to characterize ocean variability and gather enough air-sea observations at different locations to assess with accuracy the involved processes and impacts.

The western tropical Atlantic is an ideal laboratory for the proposed study. It hosts rich ocean mesoscale variability under an atmosphere characterized by a rather steady trade wind regime. In this region, eddies have a diameter of 200 to 300 km and lifetimes of several months up to years. In particular south of Barbados, very energetic and long-lived anticyclonic North Brazil Current rings are commonly found. These eddies are key for the northward transport of properties from the South to the North Atlantic within the Atlantic Meridional Ocean Circulation. Moreover, preliminary studies based on satellite observations have suggested that they play a crucial role in air-sea interactions and on the atmosphere. This region and eddies are the focus of EUREC4A-OA, the French oceanographic component of the larger EUREC$^4$A field experiments.

# V- Informations financières

## V-1 Frais

| | Coût | Niveau de financement assuré | Niveau de financement envisagé | Source de financement |
|---|---|---|---|---|
| **Frais de préparation de la campagne** | 70,000 | 20,000 | 70,000 | LEFE, ANRs, projet H2020 |
| **Frais de mission de l'équipe embarquée** | 30,000 | 0 | 30,000 | CNFH |
| **Frais d'acquisition de nouveaux matériels, contrat, sous-traitance** | | | | |
| **Frais de transport du matériel propre à l'équipe** | 35,000 | 0 | 35,000 | CNFH, ANR |
| **Frais d'analyse et de dépouillement à terre** | 100,000 | 100,000 | 100,000 | ANRs, EC H2020, CNES OTST |
| **Autres frais** | | | | |
| **Somme** | 235,000 | 120,000 | 235,000 | |

## V-2 Financement

**Financement obtenu?** Non

**Source et niveau de financement**

## V-3 Avis et signature des responsables

**Nombre de dossiers présentés par l'unité** 1

**Priorité** 1

**Avis et signature des responsables hiérarchiques du chef de mission principal**

* Voir dossier Avis et signature des responsables en fin de document

# VI- Projet scientifique

**Dossier projet***

* Voir dossier projet scientifique en fin de document

# VII- Travaux

**Stratégie et méthodologie détaillée pour atteindre les résultats escomptés***

* Voir dossier projet Stratégie et méthodologie détaillée en fin de document

**Travaux effectués à partir du bord**

| | |
|---|---|
| **Travaux en station ?** | Oui |
| | During the cruise, we will undertake underway observations of surface T, S, upper 700 m ocean velocity field, wind speed, humidity, air temperature, cloud cover and cloud thickness, aerosols, and pCO2. We will also launch regularly (4 times a day) atmospheric radiosondes |
| **Travaux en route ?** | Oui |
| | Hydrography (CTD, rosette, LADCP), Gliders deployments, MVP, VMP, OCARINA/PICCOLO deployments and recoveries, Argo floats deployments, and Atmospheric Radiosounding |

**Travaux effectués avec les engins submersibles habités (Nautile) ou non habités (AUV, SAR, SCAMPI, VICTOR, HROV ARIANE)**

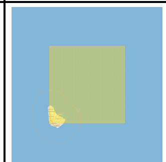
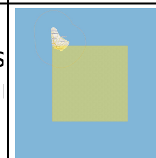
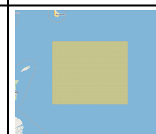
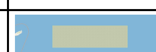
| | |
|---|---|
| **Travaux avec engins submersibles?** | Non |

# VIII- Synthèse des opérations

**Liste des opérations**

| Nom de l'opération | Nombre demandé |
|---|---|
| Hydrologie - CTD | 200 |
| Hydrologie - Niskin | 200 |
| Hydrologie - Rosette | 200 |

# IX- Déroulement prévisionnel

| Jours | Type d'activité | Nom de la zone | Latitudes | Longitudes | Vitesse de déplacemer | Type de travaux | Zone d'activité |
|---|---|---|---|---|---|---|---|
| 1-1 | Embarquem chargement | Bridgetown Harbour, Barbade | 13.106/13.1 | -59.632/-59. | 0 | Embarquem chargement montage des instruments |  |
| 2-2 | Transit & Profiles | Positionnem section méridienne anticyclone A1 | 13.11/12.2 | -59.63/-59.7 | 10 | MVP, 4 radiosondes j,déploieme gliders |  |
| 3-5 | Transit, Station & Profile | Anticyclone A1 - sect méridienne | 12.2/10.0 | -59.7/-57.0 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j |  |
| 6-6 | Transit & Profiles | Positionnem section zonale anticyclone A1 | 10.0/10.8 | -57.0/-59.5 | 10 | MVP tous les 10 km et XBT tous les 10 km en alternance | |
| 7-9 | Transit, Station & Profile | Anticyclone A1 - sect zonale | 10.8/11.5 | -59.5/-57.0 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j |  |

| Jours | Type d'activité | Nom de la zone | Latitudes | Longitudes | Vitesse de déplacemer | Type de travaux | Zone d'activité |
|---|---|---|---|---|---|---|---|
| 10-13 | Transit très lent, Station & Profile | Anticyclone A1 - soumesoécl | 11.5/12.1 | -57.8/-57.0 | 2 | CTD Rosette 2/ j, profils VMP et MVP en alternance, depl. & récup.OCAR PICCOLO, 8 radiosondes j | |
| 14-14 | Transit & Profiles | Positionnem section zonale cyclone C1 | 12.1/12.8 | -57.0/-56.0 | 9 | MVP tous les 10 km et XBT tous les 10 km en alternance, 4 radiosondes j | |
| 15-16 | Transit, Station & Profile | Cyclone C1 - sect zonale | 12.8/13.0 | -56.0/-54.3 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j | |
| 17-17 | Transit & Profiles | Positionnem section méridienne C1 | 13.0/13.6 | -54.3/-55.1 | 10 | MVP tous les 10 km et XBT tous les 10 km en alternance, 4 radiosondes j | |

| Jours | Type d'activité | Nom de la zone | Latitudes | Longitudes | Vitesse de déplacemer | Type de travaux | Zone d'activité |
|---|---|---|---|---|---|---|---|
| 18-19 | Transit, Station & Profile | Cyclone C1 - sect méridienne | 13.6/12.4 | -55.1/-54.8 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j | |
| 19-22 | Transit très lent, Station & Profile | Cyclone C1 - soumesoéch | 12.4/11.9 | -54.8/-54.6 | 2 | CTD Rosette 2/ j, profils VMP et MVP en alternance, depl. & récup.OCAR PICCOLO, 8 radiosondes j | |
| 23-23 | Transit & Profiles | Positionnem section zonale Anticyclone A2 | 11.9/10.0 | -54.6/-53.6 | 10 | MVP tous les 10 km et XBT tous les 10 km en alternance, 4 radiosondes j | |
| 24-26 | Transit, Station & Profile | Anticyclone A2 - sect zonale | 10.0/8.8 | -53.6/-56.4 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j | |

| Jours | Type d'activité | Nom de la zone | Latitudes | Longitudes | Vitesse de déplacemer | Type de travaux | Zone d'activité |
|---|---|---|---|---|---|---|---|
| 27-27 | Transit & Profiles | Positionnem section méridienne Anticyclone A2 | 8.8/7.8 | -56.4/-54.0 | 10 | MVP tous les 10 km et XBT tous les 10 km en alternance, 4 radiosondes j | |
| 28-30 | Transit, Station & Profile | Anticyclone A2 - sect méridienne | 7.8/10.7 | -54.0/-55.8 | 9 | 1 CTD Rosette tous les 10 km (5.4 NM), 1 Profil MVP entre CTDs, OCARINA/ PICCOLO 4 radiosondes j | |
| 31-31 | Transit & Profiles | Retour vers le Port de Bridgetown, Barbade | 10.7/13.106 | -55.8/-59.63 | 10 | MVP tous les 10 km et XBT tous les 10 km en alternance, 4 radiosondes j - Rangement du matériel | |

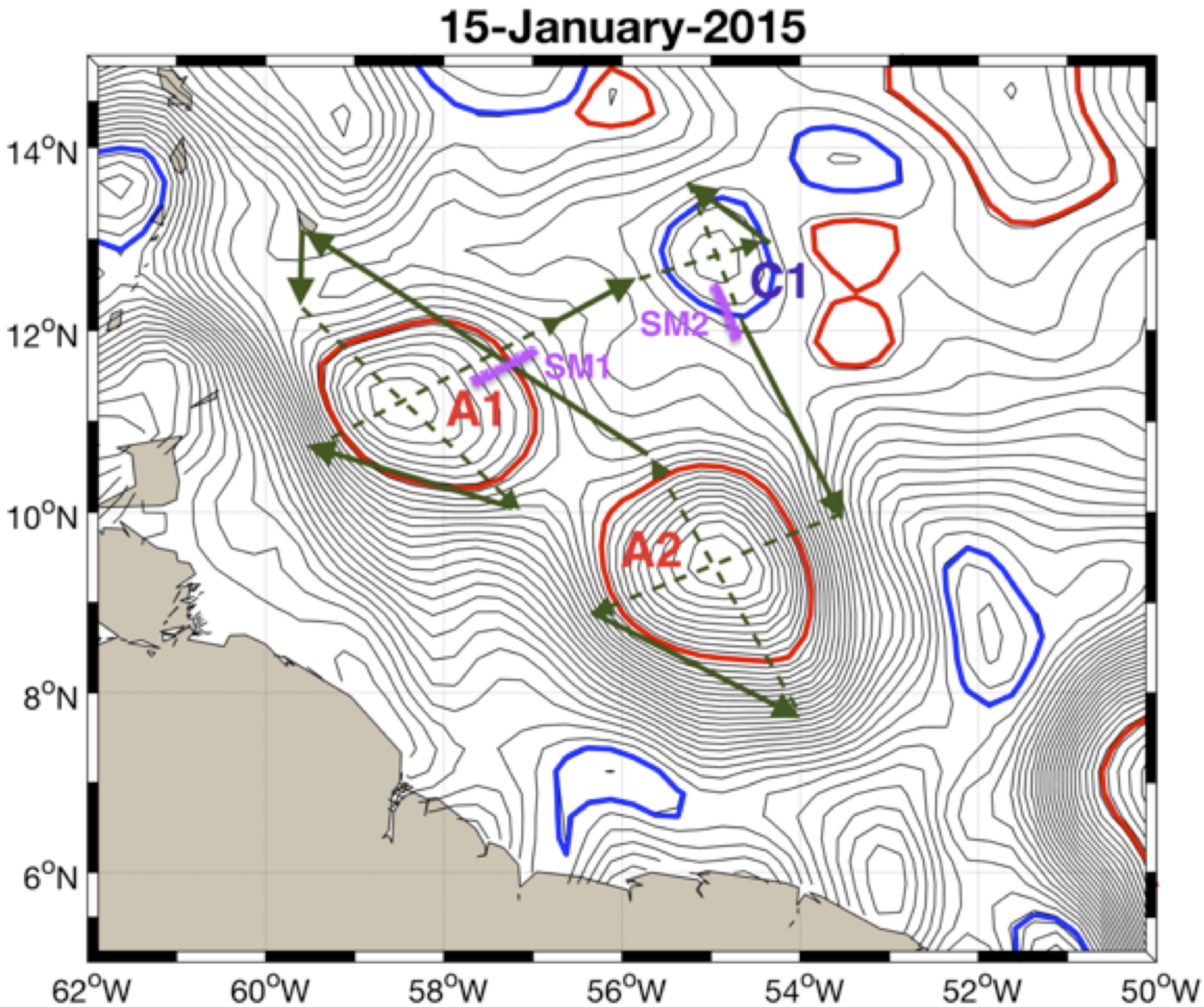
# X- Zones des travaux

| | |
|---|---|
| **Distance port d'escale - début des travaux** | 60 |
| **Distance fin des travaux - port d'escale** | 200 |

Position des zones et des stations de travail

| Nom | Nord | Sud | Ouest | Est | Profondeur (sonde) |
|---|---|---|---|---|---|

**Carte(s) de la ou des zones de travail**



# XI- Moyen navals requis

**Navires (par ordre de préférence)**

| Choix | Navire |
|---|---|
| 1 | L'Atalante |

**Justification du choix de navires**

Ce navire il nous est nécessaire par la grande quantité de paramètres océanographiques et atmosphériques que nous souhaitons observer. Il a une grande capacité pour accueillir les équipes scientifiques requises par les opérations, à l'embarquement et à la mise en oeuvre scientifique de toute l'instrumentation dont nous avons besoin et qui nous a été mise à disposition par les différents laboratoires impliqués ainsi que par nos collaborateurs internationaux

**Equipements fixes du navire**

| Nom | Commentaire | Quantité | Indispensable | Requis au leg |
|---|---|---|---|---|
| Courantomètre Doppler - ADCP 150 , 75 et 38kHz | | | Oui | |
| Courantomètre Doppler - ADCP 150 et 38kHz | | | Oui | |
| Courantomètre Doppler - ADCP 75 kHz | | | Oui | |
| Hydrologie - thermosalinomètre SBE21 | | | Oui | |
| Zodiac | | | Oui | |

**Equipements mobiles du navire**

| Nom | Commentaire | Quantité | Indispensable | Requis au leg |
|---|---|---|---|---|

**Engins**

| Nom |
|---|

**Equipements mobiles du navire**

| Nom | Commentaire | Quantité | Indispensable | Requis au leg |
|---|---|---|---|---|

**Types de laboratoire et outils informatiques demandés**

Wet-labs:
- Nutrient measurement with autoanalyser (1 entire small lab)
Dry-labs: for the following operations:
- LADCP data recording and processing, SADCP data recording and processing, thermosalinometer data recording
- Clean space for preparation of atmospheric samples

# XII- Matériel propre de l'équipe demandeuse

| Nom | Origine | A acquérir | Volume (M3) | Nombre | Poids (Kg) | Port début | Port fin | Date début | Date fin |
|---|---|---|---|---|---|---|---|---|---|
| VMP250 | LOCEAN | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| CTD, rosette et bouteilles Niskin + container | LOPS | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| Container analyse Oxygene et salinité | LOPS | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| Sea Gliders | DT INSU | Non | 0 | 2 | 0 | | | 20/01/202( | 21/02/202( |
| XBT | LMD/ LOCEAN | Oui | 0 | 200 | 0 | | | 20/01/202( | 21/02/202( |
| Flotteurs Argo | Coriolis/ EuroArgo | Non | 0 | 5 | 0 | | | 20/01/202( | 21/02/202( |
| Drifters de surface | LOCEAN/ MétéoFran | Non | 0 | 10 | 0 | | | 20/01/202( | 21/02/202( |
| OCARINA/ PICCOLO | MIO | Non | 0 | 2 | 0 | | | 20/01/202( | 21/02/202( |
| Mât Météo | MétéoFran | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| Radiosonde | MétéoFran | Non | 0 | 200 | 0 | | | 20/01/202( | 21/02/202( |
| Jenoptik Ceilometer | MPI, Hamburg, D | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| Cloud camera system | MPI, Hamburg, D | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| MVP200 ou MVP300 | DT INSU/ FOF | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| PICARRO | LOCEAN | Non | 0 | 1 | 0 | | | 20/01/202( | 21/02/202( |
| GPS | IGN - LAREG | Non | 0 | 2 | 0 | | | 20/01/202( | 21/02/202( |
| Container transport et stockage | LOPS | Non | 0 | 2 | 0 | | | 20/01/202( | 21/02/202( |

**Interfaçage**

**Liste des produits chimiques et radioactifs embarqués**

- O2 analyses : manganese chloride, sodium iodure, sodium hydroxide, sulfuric acid, sodium thiosulfate, potassium iodate

- Nutrient analyses : ascorbic acid, sulfuric acid, ammonium heptamolybdate t

**Moyens terrestres à mettre en oeuvre**

# XIII- Equipes scientifiques et techniques

## XIII-1 Equipe embarquée

| | | | |
|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Observations Météorologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Reverdin | **Prénom** | Gilles |
| **Email** | gilles.reverdin@locean-ipsl.upmc.fr | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observations chimiques et gliders |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-6518-6681 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Speich | **Prénom** | Sabrina |
| **Email** | speich@lmd.ens.fr | **Sexe** | F |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable de la stratégie à mésoéchelle |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | Ecole Normale Supérieure | **Siège social de l'organisme employeur** | Etranger |
| **Statut** | ENS | **ORCID** | 0000-0002-5452-8287 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Bellenger | **Prénom** | Hugo |
| **Email** | hugo.bellenger@lmd.jus | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable des observations air-mer, météo |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-5583-8236 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Stegner | **Prénom** | Alexandre |
| **Email** | alexandre.stegner@lmd. | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observation submésoéchelle |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0001-7882-493X |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bouruet-Aubertot | **Prénom** | Pascale |
| **Email** | pba@locean-ipsl.upmc.fr | **Sexe** | F |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observation turbulence oceanique |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | Sorbonne Université | **Siège social de l'organisme employeur** | France |
| **Statut** | ENS | **ORCID** | 0000-0001-8036-6122 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Masson | **Prénom** | Sebastien |
| **Email** | Sebastien.Masson@loce ipsl.upmc.fr | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable ADCPs |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-1694-8117 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Boucher | **Prénom** | Florent |
| **Email** | florent.beucher@meteo. | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable radiosondages |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | MeteoFrance | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bouniol | **Prénom** | Dominique |
| **Email** | dominique.bouniol@met | **Sexe** | F |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Mesures atmosphériques |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Couvreux | **Prénom** | Fleur |
| **Email** | fleur.couvreux@meteo.f | **Sexe** | F |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable analyses météo |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-8440-3362 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Roberts | **Prénom** | Greg |
| **Email** | roberts.gregc@gmail.cor | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable drone BOREAL |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-3636-8590 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Carton | **Prénom** | Xavier |
| **Email** | xcarton@univ-brest.fr | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable souméso échelle océanique |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Université de Bretagne Occidentale | **Siège social de l'organisme employeur** | France |
| **Statut** | ENS | **ORCID** | 0000-0002-7849-6611 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable mesures salinité |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable calibration Oxygène |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable Rosette |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable traitement LADCP |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Branger | **Prénom** | Hubert |
| **Email** | branger@irphe.univ-mrs.fr | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable OCARINA/PICCOLO |
| **Laboratoire** | IRPHE | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-9888-681X |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Geyskens | **Prénom** | Nicolas |
| **Email** | nicolas.geyskens@cnrs.fı | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable mesure mât météorologique |
| **Laboratoire** | DT INSU | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable fonctionnement gliders/MVP |
| **Laboratoire** | DT INSU | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Observations Météorologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Quarts Hydrologie |
| **Laboratoire** | | **Numéro Laboratoire** | |
| **Organisme employeur** | | **Siège social de l'organisme employeur** | |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

## XIII-2 Equipe de dépouillement

| | | | |
|---|---|---|---|
| **Nom** | Reverdin | **Prénom** | Gilles |
| **Email** | gilles.reverdin@locean-ipsl.upmc.fr | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observations chimiques et gliders |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-6518-6681 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Stegner | **Prénom** | Alexandre |
| **Email** | alexandre.stegner@lmd. | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observation submésoéchelle |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0001-7882-493X |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bouruet-Aubertot | **Prénom** | Pascale |
| **Email** | pba@locean-ipsl.upmc.fr | **Sexe** | F |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable observation turbulence oceanique |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | Sorbonne Université | **Siège social de l'organisme employeur** | France |
| **Statut** | ENS | **ORCID** | 0000-0001-8036-6122 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Masson | **Prénom** | Sebastien |
| **Email** | Sebastien.Masson@loce ipsl.upmc.fr | **Sexe** | M |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable ADCPs |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-1694-8117 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Boucher | **Prénom** | Florent |
| **Email** | florent.beucher@meteo. | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable radiosondages |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | MeteoFrance | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bouniol | **Prénom** | Dominique |
| **Email** | dominique.bouniol@met | **Sexe** | F |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Mesures atmosphériques |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Couvreux | **Prénom** | Fleur |
| **Email** | fleur.couvreux@meteo.f | **Sexe** | F |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable analyses météo |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-8440-3362 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Roberts | **Prénom** | Greg |
| **Email** | roberts.gregc@gmail.cor | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable drone BOREAL |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-3636-8590 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Carton | **Prénom** | Xavier |
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| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable soumésoéchelle océanique |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Université de Bretagne Occidentale | **Siège social de l'organisme employeur** | France |
| **Statut** | ENS | **ORCID** | 0000-0002-7849-6611 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable mesures salinité |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable calibration Oxygène |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable Rosette |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | thierry.terre@ifremer.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable traitement LADCP |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | UMR6523 |
| **Organisme employeur** | Ifremer | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Branger | **Prénom** | Hubert |
| **Email** | branger@irphe.univ-mrs.fr | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable OCARINA/ PICCOLO |
| **Laboratoire** | IRPHE | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-9888-681X |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | ZZ | **Prénom** | ZZ |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | CHIM | **Responsabilité et rôle à bord** | responsable observations pCO2 |
| **Laboratoire** | Univ. Rio de Janeiro | **Numéro Laboratoire** | |
| **Organisme employeur** | Université de Rio de Janeiro | **Siège social de l'organisme employeur** | Autre |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | XX | **Prénom** | XX |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable fonctionnement gliders/ MVP |
| **Laboratoire** | DT INSU | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse Hydrologie |
| **Laboratoire** | LMD | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse mésoéchelle océanique |
| **Laboratoire** | LMD | **Numéro Laboratoire** | |
| **Organisme employeur** | ENS | **Siège social de l'organisme employeur** | France |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse turbulence |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | |
| **Organisme employeur** | X | **Siège social de l'organisme employeur** | France |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse couche limite atmosphérique |
| **Laboratoire** | LMD | **Numéro Laboratoire** | |
| **Organisme employeur** | X | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse soumésoéchelle |
| **Laboratoire** | LMD | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | WW | **Prénom** | WW |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | comparaisons autres campagnes EUREC4A |
| **Laboratoire** | LEGOS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Deremble | **Prénom** | Bruno |
| **Email** | bruno.deremble@ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Dufresne | **Prénom** | Jean-Louis |
| **Email** | jean-louis.dufresne@lmd.juss | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bony | **Prénom** | Sandrine |
| **Email** | sandrine.bony@lmd.juss | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Muller | **Prénom** | Caroline |
| **Email** | caroline.muller@lmd.ens | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Risi | **Prénom** | Camille |
| **Email** | ionela.musat@lmd.jussie | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Musat | **Prénom** | Ionela |
| **Email** | ionela.musat@lmd.jussie | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | ITA | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Cuyperis | **Prénom** | Yannis |
| **Email** | yannis.cuypers@locean-ipsl.upmc.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | ENS | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Speich | **Prénom** | Sabrina |
| **Email** | speich@lmd.ens.fr | **Sexe** | F |
| **Spécialité** | OCEA | **Responsabilité et rôle à bord** | Responsable de la stratégie à mésoéchelle |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | Ecole Normale Supérieure | **Siège social de l'organisme employeur** | Etranger |
| **Statut** | ENS | **ORCID** | 0000-0002-5452-8287 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Bellenger | **Prénom** | Hugo |
| **Email** | hugo.bellenger@lmd.jus: | **Sexe** | M |
| **Spécialité** | METE | **Responsabilité et rôle à bord** | Responsable des observations air-mer, météo |
| **Laboratoire** | LMD | **Numéro Laboratoire** | UMR8539 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | 0000-0002-5583-8236 |
| **Parties de la campagne** | 1 | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse interactions air-mer |
| **Laboratoire** | LMD | **Numéro Laboratoire** | |
| **Organisme employeur** | SU | **Siège social de l'organisme employeur** | France |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | YY | **Prénom** | YY |
| **Email** | speich@lmd.ens.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | Analyse masses d'eau |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | |
| **Organisme employeur** | SU | **Siège social de l'organisme employeur** | France |
| **Statut** | DOC | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Garruste | **Prénom** | Olivier |
| **Email** | olivier.garruste@meteo.: | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Honnert | **Prénom** | Rachel |
| **Email** | rachel.honnert@meteo.f | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Lac | **Prénom** | Christine |
| **Email** | christine.lac@meteo.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Roherig | **Prénom** | Romain |
| **Email** | romain.roehrig@meteo.f | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Redelsperger | **Prénom** | Jean-Luc |
| **Email** | Jean.Luc.Redelsperger@ | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LOPS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Lothon | **Prénom** | Marie |
| **Email** | marie.lothon@aero.obs-mip.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LA | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Lionel | **Prénom** | renault |
| **Email** | renault@legos.obs-mip.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LEGOS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Jouanno | **Prénom** | Julien |
| **Email** | jouanno@legos.obs-mip.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LEGOS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Barnier | **Prénom** | Bernard |
| **Email** | bernard.barnier@cnrs.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LEGOS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Bourras | **Prénom** | Denis |
| **Email** | denis.bourras@mio.osup | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | MIO | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

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|---|---|---|---|
| **Nom** | Luneau | **Prénom** | Christopher |
| **Email** | denis.bourras@mio.osup | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | PYTHEAS | **Numéro Laboratoire** | OSU |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Williams | **Prénom** | Richard |
| **Email** | Richard.Wilson@latmos. | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LATMOS | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Testor | **Prénom** | Pierre |
| **Email** | pierre.testor@locean-ipsl.upmc.fr | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | LOCEAN | **Numéro Laboratoire** | UMR7159 |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Giordani | **Prénom** | Hervé |
| **Email** | herve.giordani@meteo.f | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

| | | | |
|---|---|---|---|
| **Nom** | Burnet | **Prénom** | Frédéric |
| **Email** | frederic.burnet@meteo. | **Sexe** | |
| **Spécialité** | | **Responsabilité et rôle à bord** | |
| **Laboratoire** | CNRM | **Numéro Laboratoire** | |
| **Organisme employeur** | CNRS | **Siège social de l'organisme employeur** | France |
| **Statut** | CHE | **ORCID** | |
| **Parties de la campagne** | | **Chef de mission** | Non |

## XIII-3 Campagnes auxquelles les membres de l'équipe demandeuse ont participé au cours des 10 dernières années

| Nom | Année | Chefs de mission |
|---|---|---|

**Liste des campagnes**

**S. Speich:**

02-03/2008 BONUS-Goodhope (RV Marion Dufresne II), Océan Austral, Chief Scientist

02/2016 M124 (RV Meteor), Atlantique Sud, Co-Chief Scientist

01/2017 MSM60 (RV MS Merian), Atlantique Sud, Co-Chief Scientist

**H. Bellenger:**

12/2015 YMC (Years of the Maritime Continent) campaign (JAMSTEC) in Sumatra, Indonesia

7/2013 PALAU2013 campaign (JAMSTEC) in Palau

9/2012 SURATLANT campaign (Iceland-Canada).

**G. Reverdin:**

2012 Strasse/SPURS1 (RV Thalassa). Chief scientist

2009 Gogasmos (RV Antea). Chief Scientist.

## XIII-4 Références scientifiques de l'équipe demandeuse

**Références scientifiques de l'équipe demandeuse**

* Voir dossier Références scientifiques de l'équipe demandeuse en fin de document

## XIII-5 Collaborations prévues

**Collaborations prévues**

EUREC4A-OA is part of a well coordinated national and international effort under the auspices of WCRP, GEWEX and CLIVAR between France (LMD, LOCEAN, LATMOS, LA, LEGOS, MétéoFrance, MIO, IRPHE), Germany (MPI Hamburg and GEOMAR), and the US (NOAA labs, UCLA, NCAR, U. Texas, ...)

# XIV- Aspects internationaux et engagements contractuels

## Aspects internationaux et engagements contractuels

* Voir dossier Aspects internationaux et engagements contractuels en fin de document

# XV - Informations juridiques

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|---|---|
| **Confidentialité** | Description, position et données publiques |

**Contrats**

| Référence du contrat | Commentaires |
|---|---|

# Curriculum Vitae


## SABRINA SPEICH

Full Professor (PR CE) Ecole Normale Supérieure

Dynamic Meteorology Laboratory UMR 8539–IPSL, Paris

sabrina.speich@ens.fr

http://www.researcherid.com/rid/L-3780-2014
http://orcid.org/0000-0002-5452-8287
https://www.scopus.com/authid/detail.uri?authorId=6602115663
https://www.researchgate.net/profile/Speich_Sabrina
https://scholar.google.fr/citations?user=G0VWQsEAAAAJ&hl=fr&authuser=1


**KEY WORDS:** Physical oceanography; Global and regional ocean circulation; Mesoscale-submesoscale interactions; Air-sea exchanges; Climate change; Shaping of the ocean dynamics on ecosystems.

## EXPERTISE

Sabrina Speich is a physical oceanographer particularly interested in the uncovering and understanding of ocean dynamics and air-sea interactions and they role on climate variability, change and related impacts. She is a world-recognized expert in ocean modeling as well as in organizing wide programs of in situ observations. Within her research projects, she has been involved since the beginning in the Argo profiling float international program. She is PI of GoodHope and BONUS-GoodHope observing programs and vice chair of the executive committee of the South Atlantic Meridional Overturning (SAMOC) international initiative. She is involved as Working package leader in the H2020 AtlantOS project. She is recently focusing her research on scale-interactions and in atmosphere-ocean dynamics, and how they affect the Earth climate and marine ecosystems under global warming. She is co-chair of the Atlantic CLIVAR Panel. She is member of the Scientific Committee on Antarctic Research (SCAR), Ocean Observations Panel for Climate (OOPC) and she is a past member of the Southern Ocean CLIVAR/CliC/SCAR Panel. She is full professor of Oceanography and Climate Sciences at the *Ecole Normale Supérieure* (ENS) of Paris and she is member of the French climate institute Pierre Simon Laplace (IPSL).

## EDUCATION

| | |
|---|---|
| 2008/12 | *Diplôme d'Habilitation à diriger des Recherches* (HDR, equivalent to the D. Sc. in the United Kingdom, to the "Libera docenza" in Italy, to the German "Habilitation") in Physical Oceanography and Climate Sciences, *Université de Bretagne Occidentale*, Brest, France; |
| 1992/11 | Ph.D. in Physical Oceanography, *Université Pierre et Marie Curie*, Paris; |
| 1989/02 | *Laurea* in Physics, *Università degli Studi,* Trieste, Italy; |

## APPOINTMENTS

| | |
|---|---|
| Since 2017 | Invited Professor, SciencesPo, Paris, France |
| Since 2014 | Dean of Studies, Department of Geosciences at the *Ecole normale supérieure* (ENS), Paris, France |
| Since 2013 | Full Professor Department of Geosciences at the *Ecole normale supérieure* (ENS) & LMD UMR 8539, Paris, France |
| 2009-2013 | Full Professor, Department of Physics at the "Université de Bretagne Occidentale", & LPO, Brest, France |
| 2009-2011 | Full Professor, Department of Physics at the "Université de Bretagne Occidentale", & LPO, Brest, France |
| 1995-2009 | Assistant Professor, Department of Physics at the "Université de Bretagne Occidentale", Brest, France |

## RECENT RESPONSABILITIES IN INTERNATIONAL COMMITTEES

| | |
|---|---|
| *Since 2017* | *Programme Committee Co-Chair, OceanObs'19, An Ocean of Opportunity (www.oceanobs19.net)* |
| *Since 2017* | *Scientific Committee of the Institut Henri Poincaré Trimester "The Mathematics of Climate and the Environment" (www.geosciences.ens.fr/CliMathParis2019.fr)* |
| *Since 2015* | *Co-chair, Atlantic CLIVAR Panel (http://www.clivar.org/clivar-panels/atlantic );* |
| *Since 2014* | *Member of the Scientific Council of the Ocean & Climate Platform (http://www.ocean-climate.org/?lang=en )* |
| *Since 2012* | *International Scientific Committee on Antarctic Research (SCAR), Member* |

## RECENT RESEARCH PROJECT RESPONSABILITIES AT INTERNATIONAL LEVEL

*Since 2015* *Working Package Leader and Member of the Executive Committee of the EU H2020 AtlantOS Project (https://www.atlantos-h2020.eu );*

*Since 2014* *Co-PI of the International Project: SOCLIM - Southern Ocean And CLIMate field studies with innovative tools (http://soclim.com );*

*Since 2007* *Co-chair of the "A monitoring system for heat and mass transports in the South Atlantic as a component of the Meridional Overturning Circulation (SAMOC) International initiative" (http://www.agence-nationale-recherche.fr/en/anr-funded-project/?tx_lwmsuivibilan_pi2%5BCODE%5D=ANR-11-IS56-0004 and http://www.aoml.noaa.gov/phod/research/moc/samoc/ ).*

*Since 2003* *PI of the international CLIVAR Project 'GOODHOPE / Southern Ocean : Monitoring the Indo-Atlantic connections. An international co-operative project. A process study and a contribution to CLIVAR - Southern Ocean" (http://www.coriolis.eu.org/Science2/Atlantic-Ocean/GOODHOPE-SAMOC )*

*2008 - 2011* *Co-PI of SCAR/IOC Southern Ocean Observing System (SOOS)*

## PARTICIPATION IN ADVISORY BOARDS AT INTERNATIONAL LEVEL

*Since 2017* *SAB member, GEOMAR Helmoltz Centre, Kiel, Germany (https://www.geomar.de/)*

*Since 2017* *PAG member, ORCHESTRA-ROSES BAS projects (https://www.bas.ac.uk/project/orchestra/);*

*Since 2015* *SAB member, Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC: https://www.cmcc.it/);*

## RECENT RESEARCH RESPONSABILITIES AT NATIONAL LEVEL

*Since 2017* *Co-Chair Climate-Ocean of the Pilote Committee 1 of the French National Agency for Science (ANR)*

*Since 2016* *Member of the "Comité spécialisé pour la recherche marine, maritime et littorale", of the Council of the Sea and Coastal Ocean, Under the auspicies of the Ministries of Research and Ecology, Paris, France (http://www.developpement-durable.gouv.fr/Le-Comite-pour-la-recherche-marine.html )*

*2009-2013* *Coordinator of the "Vulnerability of the marine system to global changes" Scientific Axis of the Institut Européen pour l'Etude de la Mer (IUEM), Brest, France;*

*2009-2013* *Scientific Committee Member of the French National Programme on the Earth Fluid Envelops and Environment (LEFE-INSU);*

*2009-2013* *Member of the Scientific Council and its Bureau, Université de Bretagne Occidentale, Brest, France;*

*2002-2009* *Principal Investigator (PI) of the "Open Ocean — Coast system exchanges" for the Ifremer programme "Ocean circulation and climate";*

## SCIENTIFIC TRAINING SERVICES

*Prof. Speich has trained about 20 PhD and postdoctoral young researchers and about 30 Master students.*

*Since 2014* *Dean of Studies of the Geosciences Department, ENS*

*Since 2014* *Member of the Doctoral School College, ED129 – Climate Sciences, IPSL, Paris*

*2010-2013* *Deputy Director of the Doctoral School on Marine Sciences, IUEM, UBO, Brest, France*

*2010-2013* *Deputy Director, Department of Physics at the "Université de Bretagne Occidentale", Brest, France*

*2001-2004* *Elected Member at the Department of Physics Council of the Université de Bretagne Occidentale*

## *RECENT OCEANOGRAPHIC CRUISES*

2017 SAMOC/AtlantOS MSM60 cruise, January 2017 South Atlantic, RV *Merian* Co-Chief Scientist.

2016 AtlantOS M124 cruise, February-March 2016 South Atlantic, RV *Meteor*. Co-Chief Scientist.

2012 Oceanographic cruise TARAOCEANS RV *Tara*. Co-PI Physical Oceanography and Climate.

2008 Oceanographic International Polar Year cruise BONUS-GOODHOPE RV *Marion Dufresne* de l'Institut Polaire Français Paul Emile Victor. Chief Scientist.

## PUBLICATIONS IN PEER-REVIEWED JOURNALS (list since 2011 only)


Laxenaire, R., S. Speich, B. Blanke, A. Chaigneau, C. Pegliasco, A. Stegner, 2018: Anticyclonic eddies connecting the western boundaries of Indian and Atlantic oceans. J. Geophys. Res. In press.

Kersalé, M., Lamont, T., Speich, S., Terre, T., Laxenaire, R., Roberts, M. J., van den Berg, M. A., and Ansorge, I. J.: Moored observations of mesoscale features in the Cape Basin: characteristics and local impacts on water mass distributions, Ocean Sci., 14, 923-945, https://doi.org/10.5194/os-14-923-2018, 2018.

Meinen, C. S., S. Speich, A. R. Piola, I. Ansorge, E., Campos, M. Kersalé, T. Terre, M. P. Chidichimo, T.

Lamont, O. Sato, R. Perez, D. Valla, M. van den Berg, M. Le Hénaff, S. Dong, and S. Garzoli, (2018) Baroclinic and barotropic flows and the dueling influence of the boundaries. Geophys. Res. Lett., DOI: 10.1029/2018GL077408

Capuano, TA, S. Speich, X. Carton, & R. Laxenaire (2018) : Indo-Atlantic exchange, mesoscale dynamics and Antarctic Intermediate Water. J. Geophys. Res. In press. DOI: 10.1002/2017JC013521

Capuano, TA, Speich, S., Carton, X., & Blanke, B. (2018). Mesoscale andsubmesoscale processes in the Southeast Atlantic and their impact onthe regional thermohaline structure. J. Geophys. Res., 123. DOI: 10.1002/2017JC013396

Carradec, Q., et al. A global ocean atlas of eukaryotic genes (2018) Nature Communications, 9 (1), art. no. 373, DOI: 10.1038/s41467-017-02342-1.

Seeleuthner, Y., et al. Single-cell genomics of multiple uncultured stramenopiles reveals underestimated functional diversity across oceans (2018) Nature Communications, 9 (1), art. no. 310, DOI: 10.1038/s41467-017-02235-3.

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L'Héveder, B., S. Speich, O. Raguenau, F. Gohin, and P. Bryère, 2016 : Observed and projected Sea Surface Temperature seasonal changes in the Western English Channel from satellite data and CMIP5 multi-model ensemble. International Journal of Climatology. DOI: 10.1002/joc.4882.

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Guidi, L., et al., 2016 : Plankton networks driving carbon export in the oligotrophic ocean. Nature. 2016 Apr 28;532(7600):465-70. doi: 10.1038/nature16942. Epub 2016 Feb 10.

Pesant, S., Not, F., Picheral, M., Kandels-Lewis, S., Le Bescot, N., Gorsky, G., Iudicone, D., Karsenti, E., Speich, S., Trouble, R., Dimier, C., Searson, S. Open science resources for the discovery and analysis of Tara Oceans data (2015) Scientific Data, 2, art. no. 150023, . Cited 45 times. DOI: 10.1038/sdata.2015.23

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Lima-Mendez, G., et al., 2015, Top-down determinants of community structure in the global plankton interactome. Science, 22 May 2015, Vol. 348 no. 6237, DOI: 10.1126/science.1262073

De Vargas, C., et al.i, 2015, Eukaryotic plancton diversity in the sunlit ocean. Science 22 May 2015, Vol. 348 no. 6237, DOI: 10.1126/science.1261605

Brum, J.R., et al., Tara Oceans Coordinators : P. Bork, C. Bowler, S. Sunagawa, P. Wincker, E. Karsenti and M. B. Sullivan (2015), Global patterns and ecological drivers of ocean viral communities, Science, 22 May

2015, Vol. 348 no. 6237, DOI: 10.1126/science.1261498

Blanke, B., S. Speich, and E. Rusciano, 2014 : Lagrangian water mass tracing from pseudo-Argo, model-derived salinity, tracer and velocity data: An application to Antarctic Intermediate Water in the South Atlantic Ocean. Ocean Modelling. 11/2014; DOI: 10.1016/j.ocemod.2014.11.004.

von Schuckmann, K., Sallée, J.-B., Chambers, D., Le Traon, P.-Y., Cabanes, C., Gaillard, F., Speich, S., and Hamon, M.: Consistency of the current global ocean observing systems from an Argo perspective, Ocean Sci., 10, 547-557, doi:10.5194/os-10-547-2014, 2014.

Meinen, C. S., S. Speich, R. C. Perez, S. Dong, A. R. Piola, S. L. Garzoli, M. O. Baringer, S. Gladyshev, and E. J. D. Campos, Temporal variability of the Meridional Overturning Circulation at 34.5°S: Results from two pilot boundary arrays in the South Atlantic, J. Geophys. Res., 118 (12), 6461-6478, doi:10.1002/2013JC009228, 2013.

Messager, C., S. Speich, and E. Key, 2012 : Marine atmospheric boundary layer over some Southern Ocean fronts during the IPY BGH 2008 cruise, *Ocean Sci.*, 8, 1001-1023, 2012.

Rusciano, E., S. Speich and M. Ollitrault, 2012 : Antarctic Intermediate Water dynamics, budget and fluxes. Interocean exchanges South of Africa. *J. Geophys. Res.* 117, C10010, doi:10.1029/2012JC008266.

Rimaud, J., S. Speich, B. Blanke, and N. Grima, 2012 : The exchange of Intermediate Water in the southeast Atlantic: Water mass transformations diagnosed from the Lagrangian analysis of a regional ocean model, J. Geophys. Res., 117, C08034, doi:10.1029/2012JC008059.

Karsenti, E., Acinas, S.G., Bork, P., Bowler, C., De Vargas, C., Raes, J., Sullivan, M., Arendt, D., Benzoni, F. 10, Follows, M. 11, Jaillon, O. 12, Gorsky, G., Hingamp, P. 3,14, Iudicone, D. 15, Kandels-Lewis, S. 1, Krzic, U. 1, Not, F., Ogata, H., Pesant, S., Reynaud, E., Sardet, C., Sieracki, M., Speich, S., Velayoudon, D., Weissenbach, J., Wincker, P., and the Tara Oceans Consortium, 2011 : A holistic approach to marine eco-systems biology. *PLoS Biology.* 9.10 (2011): e1001177. Web. 10 Feb. 2012.

Joubert W. R., Thomalla S. J., Waldron H. N., Lucas M. I., Boye M., Le Moigne F. A. C., Planchon F., Speich S.: Nitrogen uptake by phytoplankton in the Atlantic sector of the Southern Ocean during late austral summer, Biogeosciences Discuss., 8, 4917-4952, doi:10.5194/bgd-8-4917-2011, 2011.

Sarthou, G., E. Bucciarelli, F. Chever, S. P. Hansard, M. Gonzalez-Davila, J. M. Santana-Casiano, F. Planchon, and S. Speich, 2011 : Labile Fe(II) concentrations in the Atlantic sector of the Southern Ocean along a transect from the subtropical domain to the Weddell Sea Gyre. *Biogeosciences, 8, 2461–2479, 2011* *www.biogeosciences.net/8/2461/2011/doi:10.5194/bg-8-2461-2011*

Fripiat, F., A.-J. Cavagna, F. Dehairs, S. Speich, L. André, and D. Cardinal, 2011 : Silicon pool dynamics and biogenic silica export in the Antarctic Circumpolar Current inferred from Si-isotopes. *Ocean Sci., 7, 533–547, 2011, www.ocean-sci.net/7/533/2011/doi:10.5194/os-7-533-2011.*

Arhan, M., S. Speich, C. Messager, G. Dencausse, R. A. Fine, and M. Boye (2011), Anticyclonic and cyclonic eddies of subtropical origin in the subantarctic zone south of Africa, *J. Geophys. Res.*, doi:10.1029/2011JC007140.

Bown J., Boye M., Baker A., Duvieilbourg E., Lacan F., Le Moigne F., Planchon F., Speich S., Nelson D.M. 2011. The biogeochemical cycle of dissolved cobalt in the Atlantic and the Southern Ocean south off the coast of South Africa. Marine Chemistry, doi:10.1016/j.marchem.2011.03.008.

González-Dávila, M., Santana-Casiano, J. M., Fine, R. A., Happell, J., Delille, B., and Speich, S.: Carbonate system in the water masses of the Southeast Atlantic sector of the Southern Ocean during February and March 2008, *Biogeosciences*, 8, 1401-1413, doi:10.5194/bg-8-1401-2011, 2011.

Faure, V., M. Arhan, S. Speich, and S. Gladyshev, 2011 : Heat budget of the surface mixed layer south of Africa. *Ocean Dyn.*, doi: 10.1007/s10236-011-0444-1.

Dencausse, G., M. Arhan, S. Speich, 2011: Is there a continuous Subtropical Front south of Africa ?, J. Geophys. Res., 116, p. 14. doi:10.1029/2010JC006587.

## PUBLICATIONS ON DATA BASES

The GEOTRACES group (Mawji et al.), 2015 : Marine Chemistry special issue: Ocean Biogeochemistry. The GEOTRACES Intermediate Data Product 2014, Mar. Chem. (2015), http://dx.doi.org/10.1016/j.marchem.2015.04.005

Tara Oceans Expedition, Participants; Tara Oceans Consortium, Coordinators (2014): Registry of selected samples from the Tara Oceans Expedition (2009-2013). doi:10.1594/PANGAEA.840721, http://doi.pangaea.de/10.1594/PANGAEA.840721

Pesant S., F. Not, M. Picheral, S. Kandels-Lewis, N. Le Bescot, G. Gorsky, D. Iudicone, E. Karsenti, S. Speich, R. Troublé, C. Dimier, S. Searson & Tara Oceans Consortium, 2015 : CoordinatorsOpen science resources for the discovery and analysis of Tara Oceans data. Sci. Data 2:150023 doi: 10.1038/sdata.2015.23

Chaffron, S.; D'Ovidio, F.; Guidi, L.; Pesant, S.; Speich, S.; Tara Oceans Consortium, Coordinators; Tara Oceans Expedition, Participants (2014): Contextual environmental data of selected samples from the Tara Oceans Expedition (2009-2013). doi:10.1594/PANGAEA.840718, http://doi.pangaea.de/10.1594/PANGAEA.840718

# Curriculum Vitae


## Gilles Reverdin

Directeur de recherche CNRS

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**KEY WORDS:** Physical oceanography; Global and regional ocean circulation; Air-sea exchanges; isotopic geochemistry; Climate variability.

### EXPERTISE

The physical and chemical oceanography of the upper ocean in relation with the lower atmosphere: currents, temperature, salinity, oxygen isotopes of sea water and atmospheric water vapor, nutrients, CO2... Analysis of in situ or remote sensing data of the surface ocean. Coordination of observational programs in the tropical oceans, and more recently (since 1993) in the sub-tropical and subpolar North Atlantic Ocean, mostly for the surface and upper ocean (cruises: POMME, GRAVILUCK, CAROLS, GOGASMOS, STRASSE; monitoring program SURATLANT). Calibration-validation of satellite salinity missions and interpretation of SMOS satellite salinity data. Reconstruction of past-120 year Atlantic surface variability. Investigation of the water cycle, in particular through water isotopes, both in the lower atmosphere and in the ocean. Instrumental development, in particular of multi-sensor drifters.

### EDUCATION

1980/03 3d Degree thesis (Ecole Polytechnique) : Mousson Indienne au-dessus de l'océan Indien

1985/05 Thèse d'état (MNHN, Paris): Circulation de surface l'océan Indien équatorial

### APPOINTMENTS

11/1980-10/1981 Scientific military service (CETP, Paris, France); support scientist fort eh experiment on the study of African squall lines (COPT81)

1981-1989 CNRS scientist, first at LOP (until 1985), then 1985-1989 at LODYC (Paris), including 14 months at MIT and stays in Sénégal, French Polynesia and New Caledonia

1990-1994 Associate Research scientist (then Research scientist) at LDEO (Columbia Univ., New York); since then Adjunct Res. Sdcientist and since 2010 Senior Adjunct Research scientist

1995- 2001 CNRS scientsit at LEGOS, Toulouse, France

2001- CNRS senior scientist at LODYC, then LOCEAN, Paris, France

### RECENT RESPONSABILITIES IN INTERNATIONAL COMMITTEES

*Since 20xx participating to Working Group on Ocean Hydrography of ICES, and at times in SOOPIP and GOSUD*

*2008-2016 European Eurofleets and Eurofleets2 cruise selection committees*

*2014-2017 Atlantic checkpoint project of EMODNET*

### RECENT RESEARCH PROJECT RESPONSABILITIES AT INTERNATIONAL LEVEL

*None, but participated to the SPURS project on surface salinity and freshwater processes (NASA), in particular in the SPURS1 and SPURS2 experiments (2012-2017)*

## PARTICIPATION IN ADVISORY BOARDS AT INTERNATIONAL LEVEL

*None recently*

## RECENT RESEARCH RESPONSABILITIES AT NATIONAL LEVEL

| | |
|---|---|
| *Since 2001* | *Involved in Coriolis (ocean physical observations) and in particular for coordinating its R&D component* |
| *2007-now* | *Co-directing Coriolis (mostly its science component) and coordinating the SOERE CTDO2 (physical ocean observations, associated to Coriolis R&D). Currently, envisioning extension to chemical oceanography and an IR OHIS (planned for 2020)* |
| *xxxx-2017* | *Participating in various LEFE committees, most recently GMMC (as an invited member) (participated also to one ANR committee)* |
| *Since 2014* | *Member of the Scientific Council of the Ocean & Climate Platform (http://www.ocean-climate.org/?lang=en )* |

## SCIENTIFIC TRAINING SERVICES

*Gilles Reverdin has trained about 15 PhD and about 20 Master students.*

## *RECENT OCEANOGRAPHIC CRUISES*

| | |
|---|---|
| 2012 | Strasse/SPURS1 (RV Thalassa). Chief scientist. |
| 2009 | Gogasmos (RV Antea). Chief Scientist. |

## PUBLICATIONS IN PEER-REVIEWED JOURNALS (list since 2016 only)

**2018**

Chafik, L., J.E.O. Nilsen, S. Dangendorf, G. Reverdin, and T. Frederikse. North Atlantic Ocean circulation and decadal sea level change during the altimetry area. Geophys. Res. Lett., in review.

Fröb, F., A. Olsen, M. Becker, L. Chafik, T. Johannessen, G. Reverdin, and A. Omar. Mechanisms of wintertime fCO2 variability in the subpolar North Atlantic. Geophys. Res. Lett., in review

Reverdin, G., A.R. Friedman, L. Chafik, P. Holliday, T. Szekely, H. Valdimarsson, I. Yashayaev. North Atlantic extratropical and subpolar gyre variability during the last 120 years: a gridded datatset of surface temperature, salinity, and density. Part I: Dataset validation and RMS variability. Ocean Dynamics, in review

Supply, A., J. Boutin, G. Reverdin, J.-L. Vergely, and H. Bellenger. Variability of satellite sea surface salinity under rainfall. Springer Verlag, in review.

Manon Tonnard,… G. Reverdin… Dissolved iron in the North Atlantic Ocean and Labrador Sea along the GEOVIDE section (GEOTRACES section GA01). BGC, in review

Reverdin, G., N. Metzl, S. Olafsdottir, V. Racapé, T. Takahashi, M. Benetti, H. Valdimarson, A. Benoit-Cattin, M. Danielsen, J. Fin, A. Naamar, D. Pierrot, K. Sullivan, F. Bringas, G. Goni. SURATLANT : a 1993-2017 surface sampling in the central part of the North Atlantic subpolar gyre. ESSD, in Press.

Reverdin G, Alory G, Diverres D, Bringas F, Goni G, Heilmann L, Chafik L, Szekely T, Friedman A R (2018) North Atlantic subpolar gyre along predetermined ship tracks since 1993: a monthly data set of surface temperature, salinity, and density. Earth Syst Sci Data 10: 1403-1415. https://doi.org/10.5194/essd-10-1403-2018.

Benetti, M., J.-L. Lacour, A.E. Sveinbjörnsdottir, G. Aloisi, G. Reverdin, C. Risi, A.J. Peters, H.-C. Steen-Larsen. A framework to study mixing processes in the marine boundary layer using water vapor isotope measurements. Geophys. Res. Lett., published 10 March 2018 https://doi.org/10.1002/2018GL077167

Boutin, J., J.L. Vergely, S. Marchand, F. D'Amico, A. Hasson, N. Kolodziejczyk, G. Reverdin, N. Reul, J. Vialard , 2018. New SMOS Sea Surface Salinity with reduced systematic errors and improved variability. *Remote Sensing of Environment, sous presse*, RSE-D-17-00989R3.

**2017**

Benetti, M., G. Reverdin, I. Yashayaev, N.P. Holliday, E. Tynuan, S. Torres-Valdes, P. Lherminier, P. Tréguer, G. Sarthou et C. Lique. 2016. Composition of freshwater in the spring of 2014 on the southern Labrador shelf and slope. J. Geophys. Oceans, doi: 10.1002/2016JC012244.

Benetti, M., G. Reverdin, G. Aloisi, A. Sveinbjörnsdóttir, 2017. Stable isotopes in surface waters of the Atlantic Ocean: indicators of ocean-atmosphere water fluxes and oceanic mixing processes. J. Geophys. Res. Oceans, doi:10.1002/2017JC012712.

Dubois-Dauphin, Q., Colin, C., Bonneau L., Montagna, P.,Wu Q., Van Rooij, D., Reverdin, G., Douville, D., Thil F., Waldner, A., et N. Frank, 2017. Fingerprinting Northeast Atlantic water masses using Neodymium isotopes. Geochimica et Cosmochimica Acta. In Press.

Friedman, A.R., G. Reverdin, M. Khodri et G. Gastineau, 2017. A new record of Atlantic sea surface salinity from 1896 to 2013 reveals the signatures of climate variability and long-term trends. Geophys. Res. Lett., 44, 1866–1876, DOI:10.1002/2017GL072582.

Rossby, T., G. Reverdin, L. Chafik, et H. Soiland, 2017. A direct estimate of poleward volume, heat and fresh water fluxes at 59.5°N between Greenland and Scotland. J. Geophys. Res.: Oceans. http://dx.doi.org/10.1002/2017JC012835

Supply, A., J. Boutin, J.-L. Vergely, N. Martin, A. Hasson, G. Reverdin, C. Mallet, et N. Viltard, 2017. Precipitation estimates and L-Band sea surface salinity (PEALS). Quat. J. Roy. Meteor. Soc., 10.1002/qj.3110.

Yelekci O., G. Charria, X. Capet, G. Reverdin, J. Sudre, et H. Yahia, 2017. Seasonal distributions of frontal activity over the continental shelf in the Bay of Biscay. Cont. Shelf Res., 144, 65-79.

Yu, Z., C. Colin, L. Meynadier, E. Douville, A. Dapoigny, G. Reverdin, Q. Wu, K. Tachikawa, S. Wan, L. Song, Z. Xu, et F. Bassinot, 2017. Seasonal variations of dissolved eNd in the Bay of Bengal. Earth and Planetary Science Letters, Volume 479, p. 310-321.

**2016**

Bellenger, H., K. Drushka, W. Asher, G. Reverdin, M. Katsumata, W. Watanabe, et K. Ando, 2016. Extension of the prognostic model of sea surface temperature to rain-induced cool and fresh lenses. J. Geophys. Res., 121, 2841–2855, doi:10.1002/2015JC011302.

Benetti, M., H.C. Steen-Larsen, G. Reverdin, A.E. Sveibjörnsdottir, G. Aloisi, M.B. Berkelhammer, B. Bourlès, D. Bourras, G. de Coëtlogon, A. Cosgrove, A.-K. Faber, J. Grelet, S.B. Hansen, R. Johnson, H. Legoff, N. Martin, A.J. Peters, T.J. Popp., T. Reynaud, et M. Winther. Stable isotopes in the atmospheric marine boundary layer water vapour over the Atlantic Ocean, 2012-2015. Scientific

Data/Nature. Published 17 January 2017. doi:10.1038/sdata.2016.128

Benetti, M., G. Reverdin, C. Pierre, S. Khatiwala, B. Tournadre, S. Olafsdottir, and A. Naamar, 2016. Variability of sea ice melt and meteoric water input in the surface Labrador Current off Newfoundland. J. Geophys. Res. Oceans, 121, 2841–2855, doi:10.1002/2015JC011302.

Boutin, J., N. Martin, N. Kolodziejczyk, and G. Reverdin. 2016. Interannual anomalies of SMOS sea surface salinity. Remote Sensing of Environment, 180, 128-136, doi:10.1016/J.rse.2016.02.053.

Boutin, J., Y. Chao, W. Asher, T. Delcroix, R. Drucker, K. Drushka, N. Kolodziejczyk, T. Lee, N. Reul, G. Reverdin, J. Schanze, A. Soloviev, L. Yu, J. Anderson, L. Brucker, E. Dinnat, A. Santos-Garcia, W. Jones, C. Maes, T. Meissner, W. Tang, N. Vinogradova, and B. Ward, 2016. Satellite and In Situ Salinity : Understanding Near-Surface Stratification and Sub-footprint Variability. *Bull. Amer. Meteor. Soc.,* **97**, 1391–1407, doi: 10.1175/BAMS-D-15-00032.1.

Kolodziejczyk, N., J. Boutin, J.L. Vergely, S. Marchand, N. Martin, and G. Reverdin, 2016. Mitigation of systematic biases of SMOS sea surface salinity. Remote Sensing of Environment, 180, 164-177.

Sutherland, G., L. Marié, G. Reverdin, K. Christensen, G. Broström, and B. Ward, 2016. Enhanced turbulence associated with the diurnal jet in the ocean surface boundary Layer. J. Phys. Oceanogr., 39(11), 2820-2838. http://doi.org/10.1175/2009JPO4169.1.

(37 publications in 2012-2015)

### PUBLICATIONS ON DATA BASES

The SURATLANT data (1993-2017). http://www.seanoe.org/data/00434/54517/ (doi:10.17882/54517)

Gridded time series of monthly SSS in NA subpolar gyre (1993-2017).

https://doi.org/10.6096/SSS-BIN-NASG

Annual time series of SSS in Atlantic Ocean (1896-2012). http://www.legos.obs-mip.fr/observations/sss/.

Oceanographic cruise water vapor isotopic composition. 10.14768/isowvdataatlantic

All ocean isotopic water data have been communicated to the GISS database (Global Seawater Oxygen-18 Database [Schmidt et al., 1999]), but which has not yet been updated.

# Hugo Bellenger (PhD)

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Institut Pierre Simon Laplace - Université de Paris 6
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## RESEARCH EXPERIENCE

**Since 01/2018** CNRS Scientist (CR1) in LMD (UMR8539)

**2013-2017** Scientist at JAMSTEC

**2010-2013** Post-Doc position in LOCEAN (UMR)

**2008 -2010** Post-Doc position in LMD

**2007-2008** Post-Doc position in CCSR (now AORI), University of Tokyo

## EDUCATION

**2003-2007** PhD in LMD, ENS Paris.

Role of air-sea interaction in the intraseasonal variability of tropical convection. Advisor: Dr. Jean-Philippe Duvel. Defense on 9/03/2007.

**2002-2003** Masters Degree in transfer physics and radiation, Ecole Centrale Paris

**2000-2003** Engineer formation in applied physics at Ecole Centrale Paris.

## TEACHING EXPERIENCE

**2010-2011** Co-advisor for 3 Master students

**2009-2011** Teaching assistant in Mathematics, Meteorology and Oceanography and Thermodynamics of the atmosphere in Geoscience Department of Ecole Normale Paris (License-Master 2009-2011)

## PARTICIPATIONS TO IN SITU CAMPAIGNS

**12/2015** YMC (Years of the Maritime Continent) campaign (JAMSTEC) in Sumatra, Indonesia.

**7/2013** PALAU2013 campaign (JAMSTEC) in Palau.

**9/2012** SURATLANT campaign (Iceland-Canada).

**2/2007** CIRENE campaign in the tropical Indian Ocean.

**1/2007** VASCO, the Aeroclipper validation campaign in Seychelles.

## PUBLICATIONS

*16 Publications in peer-reviewed international journals, h-index 10, 1462 citations (source google scholar)*

### Selected Publications

**Bellenger H.**, K. Drushka, W. E. Asher, G. Reverdin, M. Katsumata, and M. Watanabe, 2017: Extension of the prognostic model of sea surface temperature to rain-induced cool and fresh lenses, J. Geophys. Res. Oceans, 122, 484–507, doi:10.1002/2016JC012429.

**Bellenger H.,** R. Wilson, J. L. Davison, J. P. Duvel, W. Xu, F. Lott, and M. Katsumata: Tropospheric turbulence over the tropical open-ocean: role of gravity waves, J. Atmos. Sci., 74, 1249-1271,. DOI: 10.1175/JAS-D-16-0135.1.

**Bellenger H**., K. Yoneyama, M. Katsumata, T. Nishizawa, K. Yasunaga, R. Shirooka, 2015: Observation of moisture tendencies related to shallow convection, *J. Atmos. Sci. 72, 641-659.*

**Bellenger H.**, M. Katsumata and K. Yoneyama: Turbulent mixing and its impact on lower tropospheric moisture over tropical ocean, *Geophys. Res.* Lett., 42, doi:10.1002/2015GL063868.

**Bellenger H.**, E. Guilyardi, J. Leloup, M. Lengaigne and J. Vialard, 2014: El Niño in climate models: from CMIP3 to CMIP5, *Climate Dyn.*, 42, 1999-2018.

**Bellenger H.**, and J. P. Duvel: The event-to-event variability of the boreal winter MJO, *Geophys. Res. Lett*, 39, L08701.

**Bellenger H.**, Y. N. Takayabu, T. Ushiyama and K. Yoneyama, 2010 : Role of diurnal warm layers in the diurnal cycle of convection over the tropical Indian Ocean during MISMO, *Mon. Wea. Rev*., 138, 2426-2433.

**Bellenger H.** and J. P. Duvel, 2009: An analysis of ocean diurnal warm layers over tropical oceans, *J. Climate,* 22, 3629-3646.

## REVIEWER

*Geophysical Research Letters* (AGU), *Journal of Climate* (AMS), *Journal of Geophysical Research* (Ocean and Atmosphere, AGU), *Annales Geophysicae* (European Geophysical Union), *Atmospheric Research* (Elsevier), *Ocean Dynamics* (Springer).

## ENCADREMENT

**2011** D. Bossy (University Paul Sabatier): Role of atmospheric feedbacks in the Indian Ocean interannual variability with Dr. E. Guilyardi (LOCEAN).

**2011** M-F Michel (University Pierre and Marie Curie) Observation and modelisation of the oceanic diurnal warm layers with Dr. G. Reverdin (LOCEAN).

**2010** F. Nugier (Ecole Normale Supérieure) Modeling the oceanic diurnal warm layers with Dr. J.-P. Duvel.

## TEACHING ASSISTANT

**2009-2011** Mathematics for the Earth Sciences Bachelors Degree, Geosciences department, Ecole Normale Supérieure, Paris, France.

**2009-2011** Meteorology and Oceanography for the Earth Sciences Masters Degree Geosciences department, Ecole Normale Supérieure, Paris, France.

**2009-2011** Thermodynamics of the atmosphere for the Earth Sciences Masters Degree Geosciences department, Ecole Normale Supérieure, Paris, France.

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27 Septembre, 2018

Je soussigné Philippe Drobinski, directeur du LMD, soutient sans réserve la demande d'heures de temps navire proposée dans le cadre de la réalisation d'une campagne océanique en complément de la campagne aéroportée prévue dans le contexte du projet EUREC4A. Le projet EUREC4A est un projet ERC porté par Sandrine Bony au LMD. Le projet EUREC4A–OA regroupe de nombreux laboratoires en France, en Allemagne et aux Etats-Unis et prévoit d'apporter un jeu d'observations assez complet des interactions océan-atmosphère et des premiers 1000-2000 m de l'océan, ce qui complètera les observations atmosphériques dans une région où l'océan a indiscutablement une influence primordiale sur l'atmosphère.

Ce projet est l'unique priorité du laboratoire et est fondamental pour structurer la communauté OA autour du projet EUREC4A.

Pour faire valoir ce que de droit

**Philippe DROBINSKI**
Directeur du LMD

# EUREC$^4$A-Ocean Atmosphere (EUREC$^4$A-OA)

## I. THE SCIENTIFIC PROJECT

### I.1. Scientific interest, context and state of the art

Air-sea interaction is the mechanism by which processes in one fluid drive processes in the other. It occurs primarily through mixing in turbulent boundary layers, both in the atmosphere and in the ocean, and involves exchanges through the ocean interface of radiation, sensible and latent (evaporation of water) heat, momentum and matter like condensed water, salt crystals and gas. There is increasing evidence that mesoscale processes play an important role in this interaction, but in ways that remain to be better understood and quantified.

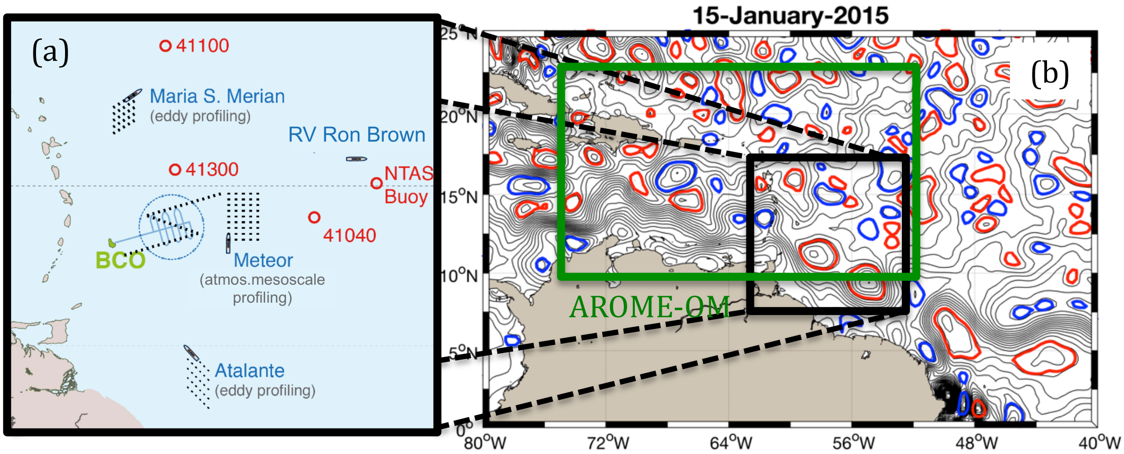


***Figure I.1.*** *(a) Observation strategy for EUREC$^4$A core campaign (the 90km radius circle track of the Halo aircraft and the winding track of the ATR42 aircraft), EUREC$^4$A ++ (RV Meteor and M. S. Merian), ATOMIC campaign (RV Ron Brown and NTAS buoy) and EUREC$^4$A –OA (RV Atalante, this proposal), BCO stands for Barbados Cloud Observatory (b) Sea surface height (contours) and anticyclonic (red) and cyclonic (blue) contours of ocean mesoscale eddies derived by applying the novel automatic eddy-tracking method of Laxenaire et al. (2018a) for 15 January 2015, the black box shows the EUREC$^4$A region and the green box shows the french model AROME Outre Mer domain.*

On the atmospheric side, over most of the oceans, weakly precipitating liquid clouds of a few thousand meters of depth drive mixing, via a process called shallow convection. This process is ubiquitous over the global ocean, particularly in the trade-wind regions, and it is critical for climate change cloud feedbacks and climate sensitivity (Bony and Dufresne 2005, Sherwood et al., 2014). Shallow convection exhibits several types of atmospheric mesoscale organizations, such as streets, clusters or 'cloud flowers', which are associated with very contrasted properties of the cloud and radiation fields (McCoy et al. 2017). However the physical mechanisms (cold pools, radiative effects…) underlying this organization remain largely unknown, and the feedback between this organization and sea surface temperatures through its coupling to surface winds, turbulence and radiation, and more generally on the ocean and the large-scale atmospheric state remains to be investigated. The role that interactions between clouds and atmospheric circulations, and the organization of convection in particular, play in climate constitutes one of the grand challenge questions of the World Climate Research Programme (WCRP; Bony et al. 2015) and at the center of the international airborne field campaign EUREC$^4$A (*Elucidating the role of cloud-circulation coupling in climate*, Bony et al. 2017, Fig. I.1a). Representation of shallow convection and its organization is one of the aims of the GEWEX Global Atmosphere System Studies (GASS) Grey Zone project (white paper in annex).

On the ocean side, mesoscale eddies are ubiquitous (Chelton et al., 2011). They can have major effects on the ocean surface energy budget, the Sea Surface Temperature (SST) field and thus on the atmospheric shallow convection. Mesoscale ocean eddies impact the atmospheric fields such as wind, clouds or rainfall, as shown from observations in the extra-tropics and in the tropics (Chelton et al., 2004; 2007; 2010; O'Neill et al., 2012; Frenger et al. 2013; Villa Boas et al. 2015), but also the momentum and heat air-sea fluxes (e.g. Bye et al 1985; Renault, et al. 2016a; 2017a; Olivier, 2018). Anticyclonic ocean eddies can be massive heat reservoirs as is the case, in the Western Tropical North Atlantic, of North Brazil Current (NBC) rings and participate to the regional and global climate as they are very effective in transferring large amount of heat from the NBC northward (Fratantoni et al. 1999; Fratantoni and Richardson, 2006). These eddies also interact with the Amazon river plume and modulate the depth of the Oceanic Barrier Layers (OBL) commonly found in this region (e.g. Ferry and Reverdin, 2004; Balaguru et al., 2012; Grodsky et al., 2012; Coles et al., 2013). These subsurface ocean layers induced by salinity stratification tend to decouple the ocean mixed layer from its deeper and colder interior. By doing so, OBL have the potential to enhance the air-sea momentum and heat exchanges, and thus to impact weather and climate (e.g., Ffield, 2007; Rudzin et al., 2018). Individual ship surveys already revealed that Sea Surface Salinity (SSS) anomalies in NBC rings are associated with air and sea-surface temperature anomalies, but the indirect contribution of the salinity stratification to the atmospheric conditions remains to be clarified. The role of ocean eddies in air-sea interactions is raising a lot of interest in the scientific community, as illustrated by the recent CLIVAR workshop co-chaired by S. Speich (Robinson et al., 2018).

The coupling of the atmosphere to the ocean under such varying oceanic conditions likely influences cloud cover and cloud properties (Frenger et al. 2013, Villa Boas et al. 2015). The rather abrupt change in SST can lead to abrupt changes in surface coupling by influencing near surface atmospheric stability. This leads to large changes in surface fluxes, and also momentum transport in the boundary layer. It has been hypothesized to influence in turn atmospheric convergence and therefore to modulate convection and the associated cloudiness and precipitation. However, the exact genesis, properties and fate of the regional mesoscale ocean eddies in terms of heat reservoir and OBL, as well as their precise influence on the Tropical Northwest Atlantic air-sea interactions, shallow convection in the atmosphere and the surface energy budget is not yet known. To advance our understanding of air-sea interaction on the ocean mesoscale motivated the design of complementary experiment to EUREC4A (Fig. I.1a): The German EUREC4A++ project (RV Meteor and RV Merian) and the American ATOMIC (RV Ron Brown) to intensively observe the regional mesoscale variability in the atmosphere and the ocean to the North and the East of the EUREC4A core campaign region. This proposal aims at complementing this observation network to the south, upstream on the oceanic eddies path.

### I.2. General objectives and research questions addressed

The **EUREC4A-OA** project will take advantage of the international EUREC4A intensive atmospheric field campaign taking place during 1 month in January-February 2020 **to observe, simulate and advance our understanding of interactions between mesoscale ocean eddies and atmospheric boundary layer features over the northwest tropical Atlantic, their impact on the ocean structure (OBL), their contribution to air-sea interactions and atmospheric shallow convection.**

The international EUREC4A airborne field campaign will take place from 20 Jan to 20 Feb 2020 over the Northwest Tropical Atlantic, near Barbados (Bony et al. 2017*,* www.eurec4a.eu). EUREC4A, which has been endorsed by WCRP (see Annex), has been designed to test critical hypotheses related to the interplay between clouds, (atmospheric) convection and circulations, and their role in climate sensitivity. Its core measurements will be derived from two research aircrafts (French ATR-42 and German HALO, Fig. I.1) equipped with an advanced remote sensing instrumentation, a dense network of atmospheric soundings from dropsondes and land-based instrumentation from the Barbados Cloud Observatory. The plan for intensive atmospheric observations during EUREC4A, and the international momentum and cooperation associated with it, are opportunities for complementary investigations.

**EUREC4A-OA** proposes to take advantage of EUREC4A to address complementary aspects albeit key for a deeper understanding of air-sea interaction and shallow convection in the Tropical Atlantic. We detail in this section the Scientific Questions (SQ) at the heart of the project and succinctly present the proposed approach or actions to address these SQs. Note that, for clarity, in the following we will use submesoscale (10m-10km) and mesoscale (10km-500km) referring to the oceanic scales. The detail of the proposed actions will be presented in the next section.

**SQ1** **What controls the evolution of oceanic mesoscale eddies and how do they interact with oceanic mean structure?**

The survey region of EUREC4A hosts a western boundary current and energetic mesoscale activity, with a corridor of NBC rings frequently observed (Johns, 2003; Dengler et al., 2004; Laxenaire et al., 2018; Olivier, 2018). NBC rings originate just north of the equator, where the reflection of Rossby waves on the Brazilian coast generates a cyclonic-anticyclonic system, which travels northwestward along this coast. Nonlinear interactions with the coast and the β-effect contribute to the growth of anticyclonic eddies (Jochum and Rizzoli, 2003). They can reach the narrow and shallow passages of the Lesser Antilles (Fratantoni et al., 1995; Fratantoni and Richardson, 2006) and influence the mesoscale activity in the Caribbean Sea (Jouanno et al. 2012) and they participate to the regional climate through heat advection and its partial release to the atmosphere (e.g., Frantantoni et al. 1999; Ffield, 2007). How the life cycle of eddies and their properties (energy, stratification, translation speed) are influenced by mesoscale air-sea interactions is still an open question. In addition, The processes by which NBC rings interact with the Amazon river plume to modulate the depth of the Oceanic Barrier Layers (OBL) commonly found in this region (e.g. Pailler et al., 1999; Mignot et al. 2012) still requires precise investigation. Moreover, preliminary results suggest that NBC rings merge with other mesoscale eddies generated within the Tropical Instability Wave (TIW) region and they are also affected by low salinity due to intense tropical precipitations (Olivier, 2018). While surveys of NBC rings have taken place in the past (Fratantoni et al., 1999; Wilson et al., 2002; Johns et al., 2003; Fratantoni and Richardson, 2006) the sampling achieved was not meant to qualify precisely the origins of water masses (NBC, Amazon and Orinoco rivers input, TIW eddies influence), small-scale processes, their role in the eddies stratification and evolution of these structures nor the effect of and on these eddies of air-sea exchanges.

Proposed approach: The survey of the eddy 3D structure is decisive to understand its evolution and the exchanges of heat, salt, momentum and nutrients with its surrounding environment. The survey will focus on a high-resolution sampling of the entire structure of the eddies, including their lower and lateral boundaries and the OBL, that are eddy regions where submesoscale variability and turbulence are thought to be particularly active. We propose to organize an intensive survey of selected mesoscale eddies using 2 ocean gliders with a focus on a region of intense submesoscale variability (Action 1, see next section), ARGO-DO (Dissolved Oxygen) profilers and a research vessel (Action 3.1). The French research vessels will realize frequent profiles of temperature, salinity, currents and turbulence parameters to reveal the 3D structure of eddies to the south of the EUREC4A region, that is upstream on the eddies path compared to the airborne campaign and to the German hydrographic survey (RV Merian, Fig. 1a). Note that the ship will also lead a submesoscale experiment in relation with the 2 gliders and the MVP high-frequency sampling for a fraction of the total campaign. These observations will be undertaken in parallel with atmospheric and air-sea fluxes to be able to understand how the air-sea exchanges affect the eddy dynamics and structure. Further interpretation of the obtained observations will be gained by using high-resolution ocean models (Action 4.1).

**SQ2 What is the impact of submesoscale and mesoscale oceanic structures on the interaction between the oceanic and atmospheric boundary layers?**

At the mesoscale, usually two main ocean feedbacks to the atmosphere are considered: the Thermal FeedBack (TFB) and the Current FeedBack (CFB). TFB consist in the SST-induced change in boundary layer stratification through surface fluxes. Low-level stability in turn controls the vertical momentum flux. By this mechanism, gradients in SST induce gradients in surface wind and stress. Seo et al. (2016) have recently suggested that the TFB, by causing oceanic vertical motions can influence eddies propagation but not their intensity. Although generally much weaker than winds, the CFB (e.g. Renault, et al. 2016) influences both the atmosphere (mainly wind and surface stress) and the ocean. By causing surface stress anomalies and, thus, oceanic vertical velocities, the CFB slows down the mean oceanic currents (e.g., Luo et al., 2005) and, by causing sink of energy from eddies to the atmosphere, the CFB induces a dampening of the mesoscale activity by ~ 30% (the "eddy killing", e.g., Renault et al., 2016b, 2017). These findings are based on modeling studies and further insights are needed on the processes implied in these feedbacks by observation and high-resolution modeling. At the submesoscale, the same feedbacks may also impact the atmosphere and in particular the boundary layer coherent structures (rolls, cells) that have comparable horizontal scale. In particular, little is known about the impact of SST front on such structures in terms of circulation and humidity distribution. This is a crucial question as these circulations and the associated creation of dry and moist regions in the lower troposphere are thought to be important to explain the organization of shallow convection (e.g. Bretherton and Blossey, 2018).

Proposed approach: To gain insight on the importance of TFB and CFB for atmospheric boundary layer and in return on oceanic structures at the submesoscale and mesoscale, one needs to map the spatial and temporal variability of the ocean interface and the associated change in boundary layer turbulence and vertical turbulent transport characteristics. This will be primarily investigated by deploying the Boréal RPAS (Action 2) to map SST, sea state and surface energy and aerosol fluxes (Roberts et al. 2017). The Boréal observations will be supplemented by near surface turbulent fluxes observation based on eddy covariance technique from the French ship and from OCARINA and PICCOLO drifting buoys (Action 3.2) and by the gliders submesoscale experiment (Action 1). These observations will be supplemented by modeling studies (Action 4.2). The impact of mesoscale oceanic variability on the atmospheric boundary layer turbulence and its coherent structures will be investigated further by running Large Eddy Simulations (LES) with horizontal resolution of 100 m or less first by forcing the LES with realistic SST fields including observed submesoscale and mesoscale variability and, if possible, by using a coupled LES representing both ocean and atmosphere boundary layers to investigate the feedback mechanisms between the two. In addition, the 5 years of the PULSATION coupled Nemo-WRF simulations (Samson et al, 2014) will be analyzed to detangle the atmosphere and ocean response to different air-sea coupling to wind, SST and ocean mesoscale structures.

**SQ3 How does the oceanic mesoscale variability influence atmospheric shallow convection on the regional scale?**

Past studies suggested different processes susceptible of explaining the observed organization of shallow convection such as the formation of cold pools by evaporation of rain (Seifert and Heus 2013). Bretherton and Blossey (2018) suggested on the other hand that the organization originate from the feedback of the convection on tropospheric humidity through moisture convergence in the boundary layer. The formation of moist patch in the lower troposphere is central for this mechanism that is certainly sensitive to the turbulent mixing within the atmospheric boundary layer and above. On the other hand, the ocean TFB and CFB on the atmosphere may also modulate wind circulations (Seo et al. 2016, Renault et al. 2016) and therefore impact convection and its organization. In addition, by modulating the ocean stratification near the surface (e.g. Mignot et al. 2012) oceanic eddies can impact the temporal variability of atmospheric shallow convection. The impact of air-sea interaction on the mesoscale on shallow convection organization and variability on the regional scale therefore remains an open question to be investigated both through detailed cases studies and statistical approach. This question is crucial to address the representation of the effect of shallow convection in regional and global models.

Proposed approach: While observations from the EUREC4A core experiment will characterize the large-scale vertical motion, the dynamic and thermodynamic properties of the atmosphere and the properties of the cloud field, EUREC4A-OA will characterize the diurnal cycle of the large-scale atmospheric state and the mesoscale variability of the ocean and of the atmosphere (radiosondes, research vessel observations, Action 3.3). This question will be further addressed by running modeling experiments (Action 4.3) with a hierarchy of ocean and atmospheric models, ranging from Large Eddy Simulation (LES) such as Meso-NH and Cloud-Resolving Models (CRM) such as SAM, that can explicitly represent convective processes on a limited area, to operational regional models coupled to a slab ocean (AROME-OM) or to an ocean general circulation model (WRF-Nemo) and global models (LMDZ, CNRM). The simulations will be compared to EUREC4A and EUREC4A-OA observations to evaluate the ability of these models to reproduce the observed diurnal cycle of the atmosphere, and the evolution of air-sea fluxes (e.g. surface latent and sensible heat fluxes), and the modification of the wind profile near the surface with varying large-scale conditions.

### I.3. Research plan, methodology and timetable

To address these 3 Scientific Questions, EUREC4A-OA proposes observation and modeling actions in close association with EUREC4A core experiment, in close cooperation with the German EUREC4A ++ (2 research vessels) and the American ATOMIC campaign (1 research vessel). The observational actions involve autonomous observing platforms (gliders and the Boreal RPAS) and the deployment of surface observing and profiling devices by a research vessel. The ship proposal associated with EUREC4A-OA will be submitted this autumn (a letter of intent has been submitted last year) for a 1-month long cruise of the RV Atalante starting in Barbados in beginning of January 2020. The modeling actions involve a hierarchy of models ranging from limited area high-resolution models for boundary layer and cloud processes to regional operational models and global climate models. Four specific actions are proposed below: Actions A1, A3.1 and A4.1 aim to answer the scientific question SQ1, actions A2, A3.2 and A4.2 will address SQ2, and A3.3 and A4.3 will address SQ3.

**Action 1 (A1) – Gliders** (LEFE budget: 26k€ incl. missions)

This action can be divided into two experiments: the main experiment (25-26 days) is a mesoscale experiment that will be supplement by shorter submesoscale experiment. This mesoscale experiment aims at tackling SQ1 by using 2 gliders during one month to continuously survey the 3D structure of selected ocean eddies and measure temperature, salinity, oxygen concentration and currents. This will be used to quantify the dynamical and thermodynamical structure of eddies, their freshwater and oxygen ($O_2$) contents, and their evolution with time. Eddies will be selected using an automated eddy-detection developed at LMD (Laxenaire et al., 2018) and applied on near-real time remote sensing images from satellites (sea level anomaly, microwave sea surface temperature, ocean color). Such detection technique will be used prior to and during the campaign to define the sampling strategies of the two gliders. This action will be supplemented by observations from the French research vessel (A3.1) and modeling activity (A4.1). The submesoscale experiment consists of a short period (5-6 days) during which the gliders and the French research vessel will focus on a limited area of intense submesoscale variability at the surface. For logistic reasons, this experiment will take place at the beginning of the ship cruise with the deployment of the gliders directly in the selected submesoscale structure. The structure selection will be based on real-time altimetry and based on the ship observation during the cruise. This will mainly aim at fueling question about interaction of mesoscale eddies and their environment (SQ1) and the study of air-sea interaction on the submesoscale (SQ2).

**Action 2 (A2) – Boréal RPAS** (LEFE budget: 55k€ incl. missions)

A2 is specifically meant to address SQ2 and consists in the deployment of the Boréal RPAS (Roberts et al 2017) during one month from the Barbados Cloud Observatory (BCO, Stevens et al. 2016) and in coordination with ATR-42 and HALO flights during the core campaign. The Boréal RPAS will probe the atmosphere from near the ocean surface (10 m) to above the marine boundary layer for up to 10h. The Boréal has been developed to map the spatial and temporal variability of SST, aerosols and turbulence (~100 km x 100 km) coordinated with the ATR/HALO aircraft operations, and will give an unprecedented insight into the boundary layer horizontal coherent structures of 100m-100km horizontal extents (cells, rolls, cold pools) and their link to ocean surface and atmospheric large-scale conditions. One of the main objectives of EUREC4A is to quantify the impact of changes in SST between warm and cold pools (~100km) of ocean eddies (mapped by the Boréal RPAS) on the atmospheric boundary layer (measured by dropsondes from the HALO) and shallow trade cumuli (via remote sensing observations on the ATR-42 and in-situ measurements on the Cloudkites). This action will be supplemented by observations from the French and German research vessels (A3.2) and modeling activity (A4.2).

**Action 3 (A3) – Oceanographic Campaign** (LEFE budget: 42k€ incl. missions)

The envisioned French oceanographic campaign (A3) is a one-month cruise to the south of the EUREC4A Core campaign region in close coordination with the German EUREC4A ++ cruise and the US ATOMIC campaign (Fig. 1a). The main objective (A3.1) of the ship will be to survey selected oceanic mesoscale eddies originating from the near-equatorial Atlantic, from NBC or local coastal currents, using different profiling and drifting devices. A3.1 thus supplements A1 to address SQ1. The second objective (A3.2) is to quantify air-sea interactions associated with these oceanic eddies and thus participate with A2 to the investigation of SQ2. Finally, A3.3 consists in frequent soundings from the ship resolving the diurnal cycle (4-8 radiosondes a day) that will be used mainly to obtain better meteorological analysis through their assimilation by sending in real time the observation to the Global Telecommunication System (GTS). This is a crucial need for obtaining an analysis suitable for atmospheric budgets derivation and to evaluate numerical simulation from Action 4. A3.3 is therefore aiming at addressing SQ3. The following present the 3 experiments of this oceanographic campaign:

***Action 3.1 (A3.1) – Oceanic eddy profiling experiment***

The French ship will be positioned south of Barbados, along the southern pathway of mesoscale eddies, and will survey the closest mesoscale structures there. The hunt for oceanic eddies will rely on the new automated eddy-detection method (Laxenaire et al. 2018) that has been presented in A1. We expect to observe eddies largest gradients at the ocean surface and just beneath the mixed layer at a depth of about 100 m. On the other hand, sub-mesoscale variability is expected to be large in the surface layer at the eddy rim and underneath the eddy core at about 1000m-depth. In order to investigate how sub-mesoscale vertical motions associated with sharp fronts at the eddy rim link the inner vortex to its environment, we will specially focus on this particular region of the eddy. For each surveyed eddy, the ship will carry out several X-shaped surveys punctuated by intensive observation stations (especially near the eddy rim) of few hours to a couple of days (8 days in total). This mesoscale experiment can be expected to include at least 3 complete eddy samplings in addition to the transit time. One can note that if only one structure is reachable by the French ship, this survey can be led three times on the same structure to document its time evolution. Intensive observation stations near eddy rims will in particular last for 3-4 days each and will consist in the submesoscale experiment described in A1. This submesoscale experiment will have to be precisely coordinated to have the ship and both gliders observing the same limited area.

During ship cruising, the ship Acoustic Doppler Current Profiler (ADCP) will be used to measure currents in the ocean upper 1000 m. In addition, Moving Vessel Profiler (MVP300) will be used to acquire profiles in the first 1000 m of salinity and temperature. Depending on sourcing of funding, we will add to the MVP additional sensors such as for oxygen, dissolved organic matter, fluorescence, etc measurements. Such vertical profiles can be acquired frequently and without interruption to achieve a good spatial resolution (a profile every 5-10km and much higher spatial resolution during the submesoscale dynamic dedicated phases of the cruise) using an automatic winch. This resolution can be augmented for temperature profiles using expendable bathythermographs (XBT). During stations (about 30-40 during one complete eddy survey), CTD and microstructure measurements will be carried out with a microstructure profiler deployed from the ships every hour to quantify turbulence and diapycnal fluxes in the water column. Five ARGO-DO profilers will be deployed in to follow the evolution (temperature, salinity ventilation) of the surveyed eddies (2 will be deployed in cyclonic eddies and 2 in anticyclonic eddies) and their environment (the last ARGO will be depoyed in between eddies). A few surface drifters measuring T, S, possibly Sea Level Pressure (SLP) at high time resolution (5 minutes) will be deployed that are requested from other projects (essentially from LOCEAN and MétéoFrance). These drifters will most likely be drogued to drift with 15-m depth currents, although a near-surface (50cm) alternative could also be considered. They could help refine locally the sampling in some mesoscale or even submesoscale features, and flow of water influenced by the Orinoco and Amazon discharges. Finally, $CO_2$ fluxes measurements will be carried out in collaboration with the National Oceanography Center.

***Action 3.2 (A3.2) – Mesoscale air-sea interaction experiment***

Concomitantly to the oceanic eddy profiling experiment (A3.1), we will carry out surface observation of the air-sea exchanges associated with the surveyed mesoscale and sub-mesoscale oceanic structures from A3.1. Two prototypes of drifting buoys from the MIO laboratory (OCARINA and PICCOLO) will provide estimates of air-sea turbulent and radiation fluxes, as well as measurements of the wind profiles in the first meter above the surface, of swell characteristics (period and significant height), and of sea surface temperature and salinity. These buoys will be deployed for 10 to 20-hour time periods from the French research vessel, which will simultaneously perform redundant measurements of air-sea fluxes. Specifically, a mast equipped to provide direct estimate of turbulent sensible and latent (evaporation) heat fluxes by eddy covariance technique will be installed at the bow of the ship. These observations are critical to monitor the atmospheric boundary layer turbulence characteristics. These observations, complemented with ship based surface meteorology parameters, skin (Infrared sensor) and 4m-depth temperature (ship Thermosalinograph) and measurements of shortwave and longwave radiative fluxes at the surface are crucial to diagnose the energy exchanges between the atmosphere and the ocean.

***Action 3.3 (A3.3) – Observation of the regional climate***

The HALO flights from the EUREC4A core campaign are designed to capture the large-scale atmospheric circulation and in particular to measure the vertical profile of horizontal mass divergence using dropsondes (Bony and Stevens, submitted). But these observations will be carried out only on three days per week over the month that the core campaign will last. Therefore, additional continuous and frequent upper air soundings are needed to be assimilated by operational centers (including ECMWF and Meteo-France) to deliver high quality analysis that can be use to diagnose large-scale budgets of mass, enthalpy, water and momentum in EUREC4A campaign region. The improvement of operational analysis for the duration of the campaign will also strongly benefit to modeling activities by getting more realistic surface forcings for ocean simulations (A4.1) and to validate model parameterizations (A4.3). The frequency of soundings on research vessels (French, German and American), BCO but also French Guyana and Guadeloupe (operated by EUMETNET) can be increased up to 4 times a day in order to resolve the diurnal cycle. Furthermore, radiosondes from the RV Merian and the French ship will document the oceanic eddies-associated variability of atmospheric mixed layer depth and of gravity waves and turbulence above. Radiosondes indeed enable to derive turbulence characteristics within the atmospheric mixed layer and above (Wilson et al. 2014) where turbulence occurrence is associated with internal gravity waves (Bellenger et al. 2017) and may affect the distribution of humidity (Bellenger et al. 2015). These observations will be complemented by analysis of satellite observations (GOES and MODIS) to characterize the cloud organization and link it with SST mesoscale patterns using Mercator 1/12° product. These diagnostics will be critical to assess models results of Action 4.3. A PICARRO LRDS analyzer will be provided by LOCEAN to analyze the isotopic composition of water vapor ($d^{18}O$ and dD). These data will provide insights on the water vapor origin, in particular whether it results from evaporation from the surface or is transported downward from the cloud layer or above (Benetti et al., 2015, 2016). Such an instrument (from ETH) will also be deployed on the ATR42, as well as on Barbados (at BCO). It is very important to get another instrument at the sea level and upstream of BCO and of the sampling area of the ATR42 to correctly interpret the airborne and ground-based measurements. This PICARRO LRDS should be deployed on-board the German ship Meteor (Fig. 1a). In addition to sampling for S and dissolved oxygen, we will carry a limited sampling for measuring surface water isotopes, as we expect in this region a variability related with the origin of the fresh water (Benetti et al., 2017), and boundary conditions in water isotopes are important to know for characterizing properties of evaporative fluxes and the surface boundary layer (Benetti et al., 2018). Observation from satellites (GOES, MODIS) will be used to characterize shallow convection organization and link it to SST and altimetry (a Master internship has been proposed on this topic).

**Action 4 (A4) – Multi-scale modeling of the ocean-atmosphere coupled system** (LEFE budget: 23k€ incl. missions)

EUREC4A and **EUREC4A-OA** will provide an unprecedented dense network of co-localized observations of the atmosphere and of the ocean in the trade-wind regime that will benefit the modeling community. At the international level (GEWEX GASS), EUREC4A has been proposed as an opportunity for the second phase of the intercomparison of models on the grey zone (resolutions between 100 m to 10 km where boundary layer and convective processes are partially resolved and parameterized). These joint modeling activities involve a hierarchy of models from Large Eddy Simulation (LES) to Numerical Weather Prediction (NWP) regional (operational such as AROME Outre-Mer or research models such as Meso-NH) and global (e.g. LMDz, ARPEGE and IFS) models. **EUREC4A-OA** modeling activities will aim at improving our understanding not only of mesoscale eddies dynamics (SQ1) and the impact of the ocean mesoscale eddies on air-sea coupling (SQ2) and the atmospheric boundary layer (SQ3) but more generally of turbulence, shallow convection and clouds in the trade-wind regimes, with a particular focus on understanding the underlying mechanisms and impact of the mesoscale atmospheric organization.

### *Action 4.1 (A4.1) – Ocean mesoscale eddies numerical experiment*

Based on A1 and A3.1 observation of eddies 3D structures, different ocean modeling experiments will be performed to study the dynamics of mesoscale eddies, their interaction with submesoscale processes and inertial or internal waves and with the mean state and in particular their role in volume, heat and fresh meridional transport in the Atlantic Ocean. This part of the project will be undertaken from different modeling perspective. The eddies modeled will be analyzed by making use of the Laxenaire et al. 2018 method that will be expanded to the 3D identification of eddies in ocean models in the coming two years (ANR SwirlingSea).

Very high resolution modeling (up to 800 m horizontal resolution) with realistic and pseudo-realistic approaches (much in the way of Capuano et al., 2018a,b numerical experiments) are planned and will use different models (Roms-CROCO and MITgcm). The Roms-CROCO modeling approach will be used to assess *via* sensitivity tests the impact of submesoscales processes on eddy stratification, evolution and properties transport as well as on air-sea forcing. One of the goal is to assess the role of the salinity in determining the ocean stratification, and, thus, modulating the air-sea coupling. This particular effort will be part of Sabrina Speich ANR “Swirling Sea” that will be submitted this autumn.

Very high-resolution (from 1/36° to 500 m horizontal resolution) realistic regional modeling will be also developed using the MITgcm to better apprehend the interaction between boundary currents and mesoscale eddies with bottom topography, continental slopes and islands and the development of submesoscale features like filaments and submesoscale eddies. Additional simulations will also be developed using the MITgcm to investigate the impact of variable surface winds and heat fluxes on the evolution of the vertical structure and the heat content of a single mesoscale eddy. The initial structure of the latter will be based on A1 and A3.1 observations of the 3D eddies structure. Such idealized model allows a fine scale representation of the mixed-layer and the internal waves within the eddy. The spatial modulation of the oceanic mixed layer, induced by mesoscale eddies will be also investigated.

Additionally, we will analyze a set of four realistic mesoscale resolving ocean and atmosphere coupled simulations from the project PULSATION (PI: S. Masson) carried out over the region 45S - 45N (Samson et al., 2014) for a period of 5 years. These simulations are designed to disentangle the TFB from the CFB (Renault et al., 2018), they differ by the coupling effects they are resolving: either the Current FeedBack (CFB) or the Thermal Feeback of SST (TFB), none or both. The impact of these coupling will be analyzed over the study area by comparing those solutions in term of e.g., vertical velocities, mesoscale activity, eddy mean-flow interactions, surface stress mesoscale anomalies, heat and momentum fluxes, SST. In particular, a generalized ω-equation (Giordani et al., 2006) will be used to unravel the processes generating vertical velocity in the oceanic submesoscale structures.

### *Action 4.2 (A4.2) – Ocean and Atmosphere boundary layer processes numerical experiment*

In order to interpret the observations from A2 and A3.2 on the impact of mesoscale and Sub-mesoscale Ocean variability (e.g. SST fronts) on the atmospheric boundary layer turbulence and horizontal coherent structure, LES simulations will be made using Meso-NH. Meso-NH and SAM will also be used in order to understand the process at work (including air-sea interaction) on shallow convection triggering and organization. Meso-NH will represent the atmosphere from the surface up to 3 km altitude (including shallow convection) with a horizontal resolution of 10-100m. The simulations will be constructed based on operational analysis (A3.3) and for cases selected among situations observed by the drone (A2) and/or the gliders and ship submesoscale experiment (A1, A3.1). In addition to a better insight on the impact of the ocean on the atmospheric boundary layer, such simulations will also constitute test beds for regional and global models (A4.3). The development of a coupled LES (atmosphere and ocean) is planned for the coming years. This tool could then be used to further understand the interaction between the two boundary layers (oceanic and atmospheric). Additionally, we will use the set of the four realistic mesoscale resolving ocean and atmosphere coupled simulations from the PULSATION (PI: S. Masson, see 4.1) project as described in Action 4.1 but focusing on the atmospheric response to the oceanic mesoscale activity. This additional analysis in a coupled framework will help us to better to evaluate the impact of the mesoscale air-sea interactions on fluxes, boundary layer height, wind and clouds and precipitations.

### *Action 4.3 (A4.3) – Impact of Oceanic mesoscale variability on the regional climate*

This action aims at evaluating the ability of kilometric resolution regional models (AROME, Meso-NH) to represent the climate of north tropical Atlantic, to validate General Circulation Models (GCMs) parameterizations to represent shallow convection and their coupling with large-scale circulation.

AROME-Outre Mer (AROME-OM), operationally run at 2.5km resolution over a large domain will be compared to EUREC4A observations (ATR42 microphysics observations, radiative fluxes, convective mass flux and cloud cover) to evaluate its parameterization for shallow convection and how it responds to actual ocean surface conditions and large-scale circulation. In particular, since December 2017, AROME-OM is run with a slab oceanic 1D mixed layer and starts from

MERCATOR analysis available at 1/12°. The data obtained with EUREC4A -OA will be used to assess the ability of this configuration to correctly reproduce the main features of the ocean-atmosphere interaction.

Global models will be used in a variety of configurations to test global climate models in a weather prediction framework to ease the comparison to observations (LMD and CNRM already have a good experience of this framework). LMDZ and ARPEGE will run global Transpose-AMIP simulations initialized by operational analyses for the length of the EUREC4A campaign. LMDZ with a zoom on the EUREC4A -OA region and guided by analyses will also be performed for the campaign duration. In addition, LMDZ-iso (Risi et al. 2010) and SAM Cloud Resolving Model (CRM) will be used to interpret PICARRO observations of water isotopes (Action 3.3). Based on these simulations, it will be possible to compare the GCMs with EUREC4A observations over short time scales and to carry out detailed process evaluations of the physical parameterizations used in the models. Simulations with Single-Column versions of the same models could complement these simulations, so as to deepen the evaluation and understanding of the model biases (a methodology tested as part of the PhD thesis of A.-A. Abdel-Lathif at CNRM). These simulations will help assess the ability of GCMs to simulate air-sea fluxes, clouds and atmospheric properties in trade-wind regimes.

**EUREC4A-OA overall schedule**

| | |
|---|---|
| 2019 | Statistics of eddies during January, training with the automated detection method.<br>Material purchase and shipping. |
| 2020 | Campaign (A1, A2 and A3), QC and analysis of the data.<br>Workshop to discuss observational results & simulations definition (A4). |
| 2021–2022 | Simulations analysis (A4),<br>Publication of results (articles and conferences). |

### I.4. Expected results

The present project aims at complementing the EUREC4A campaign by focusing on the air-sea interaction at the mesoscale that constitute for present and near-future global models a grey-zone problem: Circulations are too small to be represented explicitly, but too large and too few to be represented with the equilibrium statistical approaches required for parameterization. This project aims at structuring the ocean and atmosphere French community on this fundamental question using numerical and experimental approaches.

This project with, in particular, the results achieved by the ocean and atmosphere field operations, will be an important input for the ongoing Tropical Atlantic Observing System (TAOS) review and, more in general, for the CLIVAR-WCRP objectives. This project will result in the building of a large and comprehensive dataset on oceanic mesoscale eddies, and how they evolve under and affect in turn the overlying atmosphere detailing, in particular, the associated atmospheric boundary layer coherent structure and shallow convection organization. This dataset will be used to create a testbed for future model development: to improve the physical parameterizations of numerical weather prediction and climate models (in collaboration with the national DEPHY project), and to prepare the emergence of coupled ocean-atmosphere cloud and eddy-resolving models. The observations and simulations designed in EUREC4A-OA should fuel research well beyond the 3 years of the present proposal.

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## I.6. Effective, planned or possible participation in other regional, national and European research programs on the same issues

The ANR project "SwirlingSea: Tackling ocean eddies: Dynamics and Air-Sea Interactions in the Atlantic Ocean" (PI Sabrina Speich) will be submitted this autumn. The project focus will be on the 3D subsurface characterization and phenomenological understanding of their mesoscale eddies role in the global ocean circulation, in the transport of properties (heat, salt, carbon, oxygen, nutrients, and other biogeochemical elements) and in air-sea interactions that are still essentially uncovered. The project will use satellite and in situ observations and analyze and develop ocean modeling experiments

ANR DYNED-Atlas (PI Alexandre Stegner) will run till the end of 2019. This project is dedicated to the automatic detection of long lived eddies and the characterization of their 3D structure from a combination of altimetric data sets and the Argo profiles data-base (https://www1.lmd.polytechnique.fr/dyned/). The expertise gained on real-time detection of oceanic eddies from the AVISO/DUACS products will benefit the present project.

SHOM project Catoobs-MED (PI Alexandre Stegner) dedicated to the 3D characterization of mesoscale eddies in the Mediterranean Sea from the in-situ and remote-sensing data obtained during the PROTEVS-PERLE campaign 2018 will run till January 2020. The methodology developed during this project and the analysis of air-sea interactions of long-lived meso-scale anticyclones could be easily transposed to the present project.

Several projects in response to the European Commission (EC) 2018-2019 H2020 call for proposals have been submitted or are in a preparation stage. We are expecting the outcomes to be communicated by the EC in June 2019 and 2020.

## 1.7 Collaborations

### 1.7.1 The international context and collaborations

EUREC4A-OA is part of a well coordinated national and international effort under the auspices of WCRP, GEWEX and CLIVAR (see the endorsement letters in section 1.7.3) that will work to observe and model the tropical ocean and lower atmosphere at the ocean mesoscale and smaller scale to advance significantly our understanding of atmospheric shallow convection and the ocean mesoscale dynamics and how they interact and impact each other.

Under the international EUREC4A intensive atmospheric field campaign taking place during 1 month in January-February 2020 a coordinated action between France (EUREC4A-OA project and cruise), Germany (EUREC4A++ project and cruise), and the USA (ATOMIC project and cruise) has been set up. Germany (MPI Hamburg and GEOMAR Kiel) and the USA (NOAA but also teams from other universities and institutions) have already obtained the ship time and have committed with two German ships – the RVs MS Merian and Meteor – and one American, the RV Ron Brown. We have developed a common strategy and will organize the cruises and data analyses in a well-coordinated effort. We will prepare the field work starting this December 2018, during the AGU Fall meeting in Washington DC (USA).

### I.7.2 The national EUREC4A-OA team

| Nom | Title | Institution | Task | Implication (%) |
|---|---|---|---|---|
| Hugo Bellenger | CR | LMD | A3.2 Ship surface meteorology<br>A3.3 Radiosondes analysis | 50% |
| Sabrina Speich | PR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD)<br>A4.1 Oceanic simulation ROMS-CROCO<br>A3.2 Air-sea interactions | 30% |
| Sandrine Bony | DR | | A2 Coordination with EUREC4A ; Analysis of the mesoscale variability of shallow convection | 5% |
| Bruno Deremble | CR | | A4.1 Oceanic Simulations with MITgcm | 15% |
| Jean-Louis Dufresne | DR | | A4.3 Regional energy closure observations/models | 10% |
| Frédéric Hourdin | DR | | A4.3 LMDZ guided simulations & clouds evaluation | 5% |
| Ionela Musat | IR | | A4.3 LMDZ/IPSL transpose AMIP simulations | 10% |
| Caroline Muller | CR | | A4.2 SAM LES atmospheric simulations | 20% |
| Camille Risi | CR | | A3.2 A4.3 LMDZ-iso simulation and analysis | Expert |
| Alexandre Stegner | CR - PR X | | A3.1 ADCP, CTD, Turbulence<br>A4.1 Oceanic simulation | 25% |
| Raphaela Vogel | Post-Doc | | A3.3 Study of shallow clouds and convective organization using EUREC4A observations | Expert |
| Pascale Bouruet-Aubertot | PU | LOCEAN | A3.2 Microstructure profiler analysis | 0-15-15% |
| Yannis Cuypers | MCF | | A3.2 Microstructure profiler analysis | 0-15-15% |
| Pierre Testor | CR | | A1 Gliders strategy and analysis | 10% |
| Gilles Reverdin | DR | | A3.1 Drifters<br>A3.2 PICARRO & isotope samples | 10% in 2019 20% in 2020 |
| Sébastien Masson | PA | | A4.1 A4.2 WRF-Nemo simulations | 20% |
| Florent Beucher | ITM | CNRM | A4.3 AROME-OM evaluation | 50% |
| Dominique Bouniol | CR | | A3.3 Satellite observation | 10% |
| Frédéric Burnet | CR | | A2 Boréal RPAS measurements | 10% |
| Guylaine Canut | CR | | A2 Turbulence measurements | Expert |
| Fleur Couvreux | ICPEF | | A4.2 LES simulations shallow convection organization<br>A4.3 Process oriented evaluation of AROME-OM | 15% |
| Ghislain Faure | IDT | | A4.3 AROME-OM coupled model | 5% |
| Olivier Garrouste | IR | | A3.3 Radiosondes observation | 5-10-5% |
| Hervé Giordani | CR | | A4.1 Analysis of ocean vertical motions<br>A4.2 & A4.3 Analysis of coupled boundary-layers processes | 15% |
| Rachel Honnert | CR | | A4.3 AROME-OM evaluation | 15% |
| Christine Lac | ICPEF | | A4.3 Meso-NH regional | 10% |
| Greg Roberts | CR | | A2 Boréal RPAS measurements | |
| Romain Roehrig | IPC | | A4.3 Arpege-climat simulations & analysis | 5% |
| Jean-Luc Redelsperger | DR | LOPS | A4.2 Coupled boundary layer LES simulations | 15% |
| Xavier Carton | PR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD)<br>A4.1 Oceanic simulations | 15% |
| XX | IR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD) | 15% |
| XX | IR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD) | 15% |
| XX | IR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD) | 15% |
| XX | IR | | A3.1 Ship hydro (ADCP, XBT/MVP300, CTD) | 15% |

| Nom | Title | Institution | Task | Implication (%) |
|---|---|---|---|---|
| **Marie Lothon** | CR | LA | A2 Design and analysis of ATR-42 turbulence measurements | 10-15-15% |
| **Lionel Renault** | CR | LEGOS | A4.1 & A4.2 WRF-NEMO coupled simulations analysis | 25% |
| **Julien Jouanno** | CR | | A4.1 & A4.2 WRF-NEMO coupled simulations analysis | 20% |
| **Bernard Barnier** | DR | | A4.2 Air-sea interaction at mesoscale | Expert |
| **Richard Wilson** | MCF | LATMOS | A3.3 Radiosondes analysis, atmospheric turbulence | 10% |
| **Andrea Doglioli** | MCF | MIO | A3.1 Expertise MVP200 data analysis, submesoscale dynamics, campaign strategy | 5% |
| **Bourras Denis** | CR | MIO | A3.2 Estimation of Air-Sea turbulent fluxes OCARINA, PICCOLO and RV mast, wave characteristics and wind profile | 20% |
| **Branger Hubert** | CR | IRPHE | A3.2 Estimation of Air-Sea turbulent fluxes OCARINA, PICCOLO and RV mast, wave characteristics and wind profile | 20% |
| **Luneau Christopher** | AI | OSU Pytheas | A3.2 Deployment of OCARINA and PICCOLO buoys | 5% |
| **Nicolas Geyskens** | IR | DT INSU | A3.1 Mast for Turbulence observations | Expert |
| **Jeanne Melkonian** | IR | DT INSU | A.1 Gliders operations | Expert |

### I.7.4 Endorsements

The World Climate Research Programme endorsement letter for EUREC4A: http://eurec4a.eu/fileadmin/user_upload/eurec4a/documents/2018-let-WCRP-EUREC4A_endorsement.pdf

CLIVAR letter of endorsement of EUREC4A-OA: http://www.clivar.org/news/atomic-and-eurec4a-oa-have-been-endorsed-clivar

### I.8. Risks

The operation of Boréal RPAS from Barbados is conditioned to obtaining a license from Barbados authorities. However, the regulation to operate drones in Barbados has been recently relaxed and discussions to obtain the license have been undertaken. http://www.telecoms.gov.bb/website/index.php?option=com_content&view=article&id=95:drones-how-to-apply-for-a-temporary-exemption&catid=8:pages

In case the French research Vessel proposal is not funded, the available sensors, such as radiosondes, XBT probes, PICARRO or microstructure profiler will complement the equipment onboard the German ships (EUREC4A++ project) and/or the American ship (ATOMIC project). Then the LEFE funds originally planned for radiosondes and XBTs will be used to ship the instruments to the German ships. Possible remaining will be used to reinforce the present budget to be used for publications and workshop/conferences.

In case MVP300 is acquired, the budget devoted to XBTs can be re-deployed partly as radiosondes to increase the frequency of soundings and thus the quality of analyses or for missions and publications for modelers from Swirling Sea ANR (PI Sabrina Speich) in case it is not funded. In the case MVP300 is not acquired, DT INSU MVP200 will be used, this profiler does not enable profiling below 200m, in this case XBTs will be necessary to get profiles down to the bottom of oceanic mesoscale structures.

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# EUREC4A-Ocean Atmosphere (EUREC4A-OA)

## DESCRIPTION OF THE OCEANOGRAPHIC CRUISE

### II. STRATEGY AND IMPLEMENTATION PLAN

Mesoscale eddies, are omnipresent in the ocean. Observations from satellites, moorings, and autonomous floats show that eddies differ from their surroundings (e.g., Frenger et al., 2013, Sun et al., 2018) and can transport oceanic heat and salt over large distances (Laxenaire et al., 2018b). The imprint of eddies on sea surface temperature affects the overlying atmosphere, and these interactions feed back to affect the eddies themselves. With rapid advances in numerical modeling, climate models, for the first time, have sufficient resolution to capture these eddies and their interactions with the atmosphere. As we learn more about the rich dynamics of these ubiquitous features, three questions emerge: How can we use direct measurements to better assess eddy interactions with the atmosphere? How do such interactions affect ocean dynamics? Can eddies, despite their small size, influence weather and climate? These questions were at the center of this year CLIVAR workshop on ocean eddies (Robinson et al., 2018). The workshop highlighted how there is increasing evidence that the temperatures associated with the eddies influence winds in the atmospheric boundary layer by modulating atmospheric pressures and vertical mixing (Sugimoto et al., 2018). Winds, in turn, affect how hard the atmosphere pushes on the ocean surface, as do the eddy currents themselves (Renault et al. 2016b). Also recent observations suggest a key role of the ocean mesoscale eddies in exchanges of heat and moisture with the atmosphere. Moreover, new model results suggest that the atmosphere, at weather scales or larger, responds to cumulative effects of the much smaller ocean eddies (Ma et al., 2016a; 206b). All these preliminary results indicate a consequent effects of ocean eddies and their associated air-sea exchanges on ocean and atmosphere energies, circulation and changes.

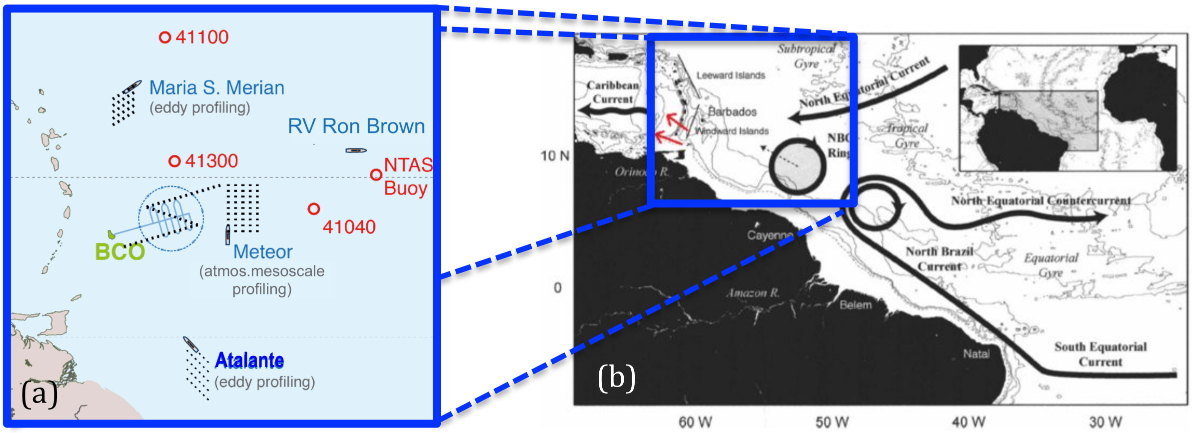


***Figure II.1.*** *(a) Observation strategy for EUREC4A core campaign (the 90km radius circle track of the Halo aircraft and the winding track of the ATR42 aircraft), EUREC4A ++ (RV Meteor and M. S. Merian), ATOMIC campaign (RV Ron Brown and NTAS buoy) and EUREC4A-OA (RV Atalante, this proposal), BCO stands for Barbados Cloud Observatory (b) Circulation in the western tropical Atlantic Ocean showing predominant currents and the formation of North Brazil Current Rings. The 200m (dashed), 1000m, 2000m, and 4000m depth contours are shown (adapted from Fratantoni & Richardson, 2006). Two small red arrows have been superimposed to represent the current inflows into the Caribbean basin. The blue box shows the EUREC4A region.*

Most of the studies on mesoscale ocean eddies only and those on their imprint on the atmosphere have been focusing in the extra-tropics (Frenger et al. 2013; Villa Boas et al. 2015; Ma et al. 2016), where mesoscale dynamics is particularly energetics. However, preliminary results show that the tropics are also characterized by intense mesoscale eddies (Olivier, 2018; XXX, Chelton et al., 2011) and they are likely to affect the atmosphere in different ways (Ffield et al., 2007; Baluguru et al. 2012; Olivier, 2018), including perhaps a role in the atmosphere shallow and deep convection. Within this framework, the objectives of the EUREC4A-OA oceanographic field experiment is to be better understand and quantify the role of the Northwest Tropical Atlantic Ocean ocean eddies in the uptake and advection of heat, salt and oxygen. We will focalize in the southern part of the EUREC4A core region under the influence of the North Brazil Current (NBC), North Equatorial Current (NEC) and North Equatorial Counter Current (NECC; Fig.II.1).

This region is a particularly eddy rich environment. By using the new eddy tracking method of Laxenaire et al. 2018a, we were able to robustly assess the geographical persistence and intensity of mesoscale eddies (Olivier, 2018). Here, an intense eddy activity appear along the South American coast with a relatively large and uninterrupted band of anticyclones (Figure I.2a) reflecting the continuous presence and northward path of NBC rings (Olivier, 2018; Fratantoni et al., 1999; Fratantoni and Richardson, 2006). Similar to the well known Agulhas Rings in the South Atlantic (e.g., Laxenaire et al., 2018a,b), the NBC rings are important transport agents of water masses from the southern into the northern Atlantic Ocean and thereby contribute to the upper limb of the Atlantic Meridional Overturning Circulation (AMOC: Johns et al., 2003). Cyclonic eddies are also present, albeit less constrained geographically. However, their presence is robust and located offshore of the anticyclone eddy band (Olivier, 2018; Figure I.2b).

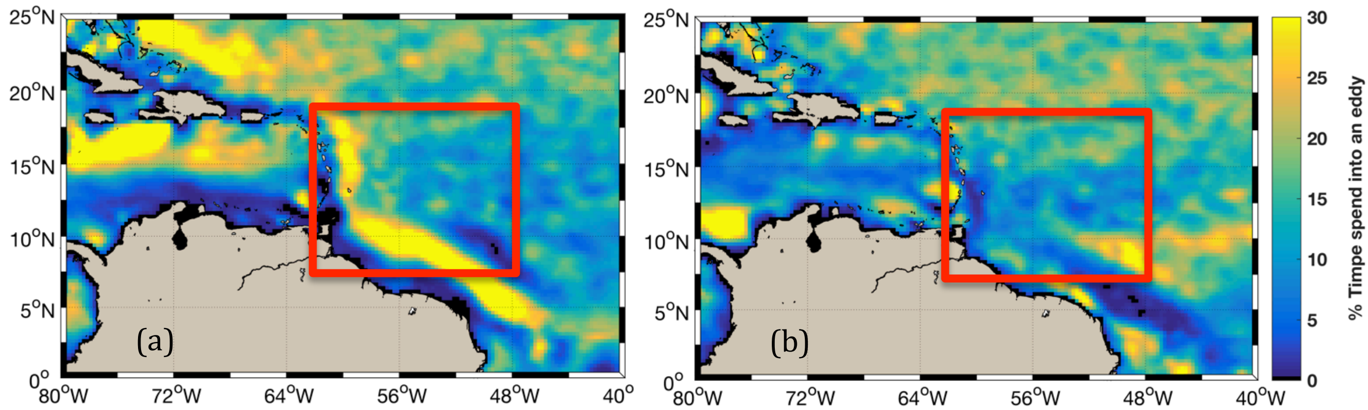


***Figure II.2.*** *Long-term mesoscale eddies occurrence derived from satellite altimetry (Laxenaire et al. 2018a) (a) Anticyclonic eddies (b) Cyclonic eddies. Adapted from Olivier, 2018. The red box shows the EUREC*[4]*A region.*

The southern region of the EUREC[4]A box is also characterized by the strong influence of fresh water advection of different origins, from the Amazon and Orinoco rivers, and the precipitation in the ICTZ band (Ferry and Reverdin, 2004; Ffield, 2007; Coles et al., 2013). This freshwater layer is found near the Barbados region during the summer and fall season (Figure II.3a) and also during the winter season (Figure II.3c). Its northward advection from the source regions is very likely ruled by mesoscale eddies that therefore impact the meridional transport of properties. It also strongly affect the ocean mixing layer by inducing the development of an Ocean Barrier Layer (OBL) that strongly control the SST as well as the buoyancy and momentum exchanges with the atmosphere (Figures II.3c and II.4).

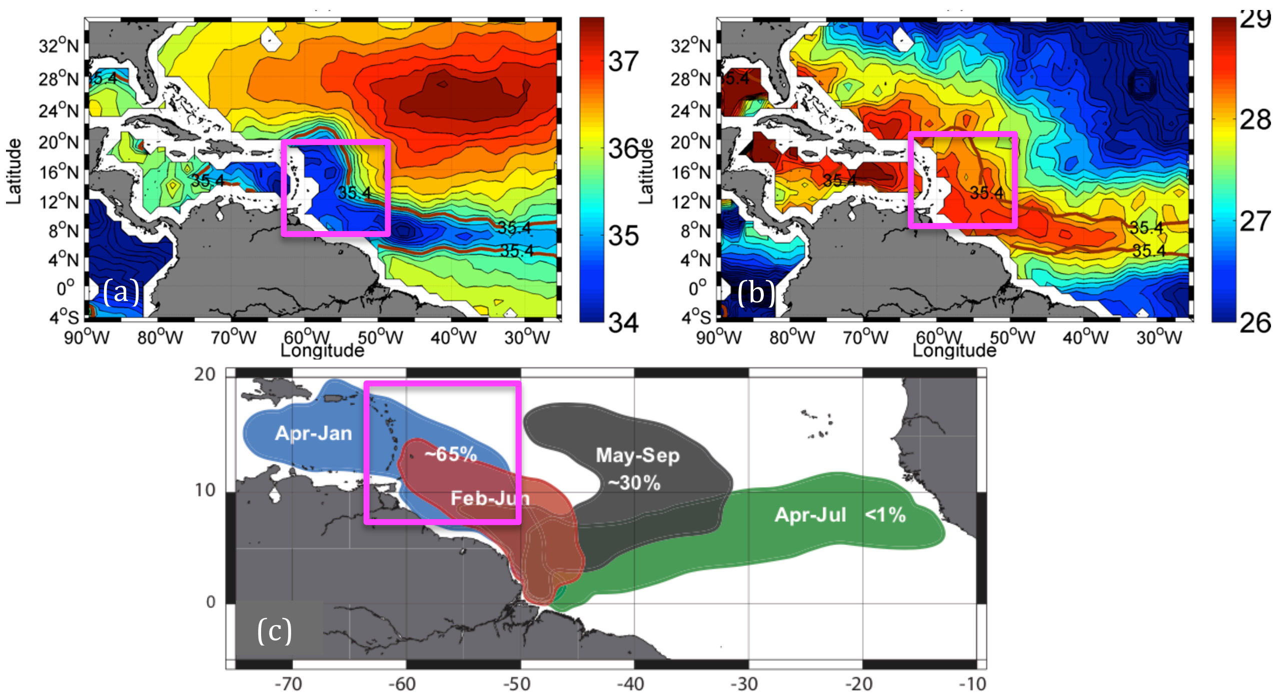


***Figure II.3.*** *Historical distribution of (a) SSS and (b) SST (in unit of °C) in the North Western Tropical Atlantic during the hurricane peak season (August through October). Adapted from Reul et al. 2014. (c) Schematic of float transport pathways with primary month range for initialization, and the percentage of drifters that follow each pathway in numerical simulations (adapted from Coles et al., 2013). The brown curve in panels a and b is showing the historical extent of the Amazon-Orinoco river plume (surface isohaline at 35.4). The magenta box shows the EUREC*[4]*A region.*

The coupling of the atmosphere to the ocean under such varying SST (and SSS) conditions likely influences cloud cover and cloud properties. Moreover, the rather abrupt change in SST at the edge of eddies can lead to abrupt changes in surface coupling by influencing near surface stability. This in turns induces large changes in surface fluxes, and also momentum transport, and has been hypothesized to influence atmospheric convergence, cloudiness, and perhaps also trigger precipitation. From dedicated ship and glider studies in the eastern tropical Atlantic it has been shown that also in the tropical ocean, mesoscale eddies often preserve SST and SSS anomalies over extended periods of time (months, e.g. Schütte et al. 2016). This is possibly related to submesoscale processes, in particular near inertial internal waves, which are part of the eddies dynamical regime (Karstensen et al. 2017; Pietri & Karstensen 2018).

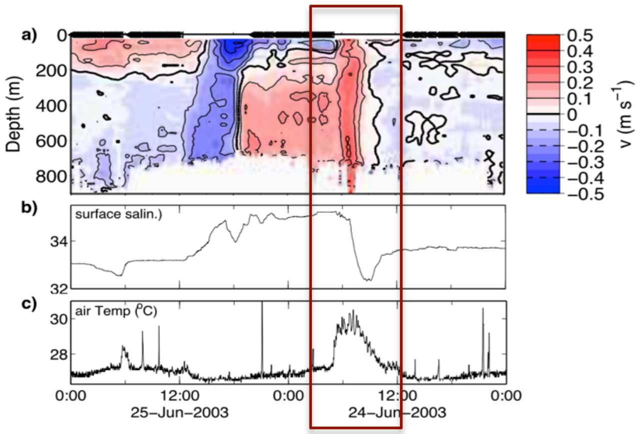


***Figure II.4.*** *Two days RV SONNE (SO172) ship survey through an anticyclonic eddy (North Brazil Current Ring) west of Barbados (ship was going east to west, time axis is reversed for clarity). a) Meridional current section (triangles at 0 m denote ship was stationary), b) sea surface salinity (psu), and c) air temperature (Bony et al. 2017). The eddy structure is visible in the red box for the different variables.*

The EUREC$^4$A-OA oceanographic cruise aims at documenting extensively and at ground-breaking resolution, the structure, and evolution of mesoscale eddies, as well as the implicated processes driving their dynamics and properties transport together with the associated air-sea interactions. We will focus on the NBC rings region, just south of Barbados, where these processes are particularly active and are the most noteworthy of the Tropical Atlantic.

EUREC$^4$A-OA has more specifically three objectives that shape the oceanographic cruise. They are:

**SQ1 What controls the evolution of oceanic mesoscale eddies and how do they interact with oceanic mean structure?**

Proposed approach: A survey of the three eddies 3D structure to understand its evolution and the exchanges of heat, salt, momentum and nutrients with its surrounding environment. The survey will focus on a high-resolution sampling (5 km) of the entire structure of the selected eddies, including their lower and lateral boundaries and the OBL. We will use two ocean gliders, ARGO-DO profilers and hydrography from the research vessel. We will also undertake two submesoscale experiments by implementing an *ad hoc* use of the 2 gliders, MVP high-frequency sampling and VMP profiles. These observations will be undertaken in parallel with measurements of the lower atmosphere and air-sea fluxes to assess the linkage between the ocean and the atmosphere at the ocean mesoscale and how these air-sea exchanges affect the eddy dynamics and structure.

**SQ2 What is the impact of submesoscale and mesoscale oceanic structures on the interaction between the oceanic and atmospheric boundary layers?**

Proposed approach: This will be primarily investigated by deploying the Boréal RPAS to map SST, sea state and surface energy and aerosol fluxes (Roberts et al. 2017). The Boréal observations will be supplemented by near surface turbulent fluxes observation based on eddy covariance technique from the French ship and from OCARINA and PICCOLO drifting buoys and by the gliders submesoscale experiment.

**SQ3 How does the oceanic mesoscale variability influence atmospheric shallow convection on the regional scale?**

Proposed approach: EUREC$^4$A-OA will characterize the diurnal cycle of the large-scale atmospheric state and the mesoscale variability of the ocean and of the atmosphere via radiosounding and direct atmospheric and air-sea fluxes observations from the French research vessel.

The EUREC$^4$A-OA oceanographic cruise will contribute to the larger EUREC$^4$A field experiment which, with its widespread and comprehensive ocean and atmosphere sampling, promises to be the most significant field study of the trades ever.

### II.2 – Cruise implementation

The project will undertake an integrated oceanographic transect in the region south of Barbados with an ocean-atmosphere multidisciplinary approach. We will observe simultaneously the upper 1500 m – 2000 m of the ocean and the lower atmosphere (including the two boundary layers) physical and (for the ocean) biogeochemical parameters with the state-of-the-art methods listed below.

The overall strategy of the campaign is to conduct ocean-atmosphere observations of two (2) anticyclonic eddies and one (1) cyclonic eddies south of Barbados Island. Station sampling will be limited to the first 1500 m of the water column except during the deployment of the 5 Argo floats where we will sample down to 2000 m of depth.

A dedicated ship based experiment, that targets high-resolution ocean/atmosphere observations in mesoscale eddies, requires flexibility in selecting the appropriate survey area. We have prepared this cruise proposal and related operations by carrying out a detailed study on the presence and position of ocean mesoscale eddies around the Barbados Island using mainly satellite altimetry observations, but also temperature, salinity and air-sea heat flux estimations. This work was the subject of a six-month internship of Léa Olivier (Olivier, 2018). The report of this work is attached as an appendix.

Olivier (2018) allowed us to characterize a continuous presence of anticyclonic and cyclonic eddies south of Barbados. We have performed ship time calculations for transits and measurement sections from eddy maps over the past 20 years by taking the characteristic sizes of these structures, their distances from the island and from each other. The closest eddies are located at a distance of less than 500 km from the island (see for example Fig. II.5 where are depicted three snapshots for January 15 at different years).

Two months before the campaign, we will know the generic position of the three vortex structures that we are targeting through the analysis of satellite observations in near real time mode. These analyses are carried out in real time using the eddy detection method developed by Laxenaire et al (2018a), which has already proven to be very robust in the organization and implementation of many recent oceanographic campaigns. We will refine the exact cruise plans starting two months prior to the operations at sea.

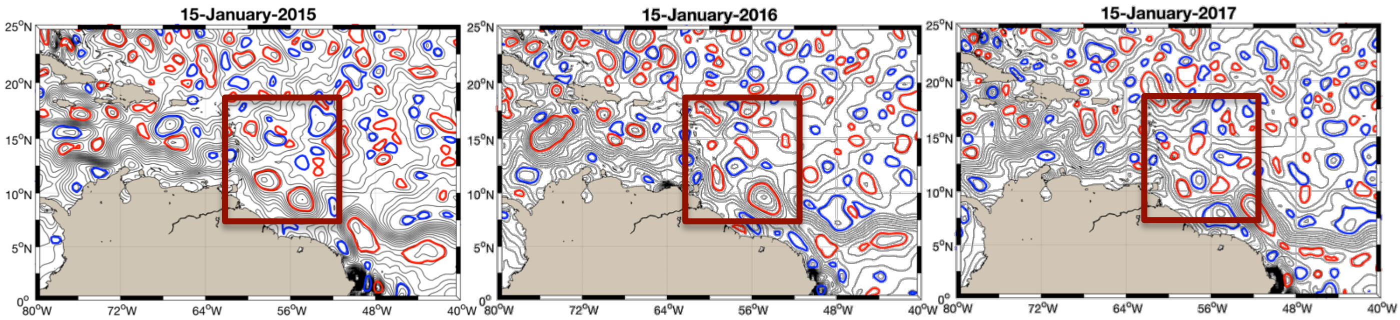


***Figure II.5.*** *Sea surface height (contours) and anticyclonic (red) and cyclonic (blue) contours of ocean mesoscale eddies derived by applying the novel automatic eddy-tracking method of Laxenaire et al. (2018a) for the 15 of January a) 2015, b) 2016 and c) 2017. The dark red box shows the EUREC4A region.*

During the cruise, we will undertake underway observations of surface T, S, upper 700 m ocean velocity field, wind speed, humidity, air temperature, cloud cover and cloud thickness, aerosols, and $pCO_2$.

We are planning different type of stations:

1) **Hydrographic stations** (**H** stations, 200 in total, 1.5 hours each) will consist of one CTD/Niskin rosette-cast (0 m – 2000 m, 12 depths). This will constitute the physical and biogeochemical background to evaluate water mass characteristics and transport calibrated via hydrology, LADCP, and extrapolated in time and space via satellite altimetry, SST and SSS fields (e.g., Legeais et al., 2005; Swart and Speich, 2010; Hutchinson et al., 2015).

2) MVP underway stations (**MVPu** stations, 200 in total) will consist of the deployment of the MVP between two CTD stations to increase the horizontal resolution of T, S and Oxygen profiles and better characterize the 3D structure of eddies, eddy edges and water flows outside of the eddies.

3) Argo stations (**Argo** stations, 3 station to deploy a total of 5 Argo with Oxygen sensor) will consist of the deployment of 2 Argo floats in the core of two eddies, one anticyclonic and one cyclonic, and one float in between eddies. At each Argo station we will undertake a 2000 m hydrological profile for later validation and calibration of the float data (it will correspond to three of the 200 H station already mentioned).

4) OCARINA/PICCOLO (**OP**, daily deployment, so about 20 days of deployment) are two prototypes of drifting buoys from the MIO laboratory that will provide estimates of air-sea turbulent and radiation fluxes, as well as measurements of the wind profiles in the first meter above the surface, of swell characteristics (period and significant height), and of sea surface temperature and salinity. These buoys will be deployed for 10 to 20-hour time periods which will simultaneously perform redundant measurements of air-sea fluxes.

5) Radiosondes (**RS**, 4 times a day, at 00:00, 06:00, 12:00, and 18:00 GMT, so about 120 stations) will consist of underway launching at precise times of the day to document the local vertical profile of the troposphere (in and out of the eddies), how it changes during the day cycle and with different environmental conditions. It will also allow, by assimilation in regional models ad hoc developed during the operations period of EUREC4A, to describe the large scale atmospheric circulation in the Tropical Atlantic.

6) Gliders stations (**GL**, deployed at the beginning of the cruise and recovered at the end of the cruise). They will sample during the operations period one or two of the eddies we will target during EUREC4A-OA. They will also be programmed to combine and come near the ship during the 2 periods of submesoscale sampling. At the end of the cruise we will recover them before heading to Bridgetown Harbour again.

**7)** Submesoscale stations (**Sub**, they will occur two times, as 4-day periods) will consist of enhanced sampling in a very restricted area of two eddies, one anticyclonic and one cyclonic (see Fig. II.6). In this context, we will carry out stations very close in space and time, with the deployment of CTD but especially MVP to gather high-resolution profiles of T, S and Oxygen, the VMP to gather turbulence estimates in the first 1000 m of the water column.. The two gliders will be located near the ship to complete the 3D ocean observation at these scales. The ship will advance at 4 kt or less. The OCARINA/PICCOLO, the meteorologic mast and radiosounding will gather high-resolution measurement of the overlying atmosphere to disentangle the influence of submesoscale ocean dynamics from the mesoscale.

The originality of this work is the strong coupling between physical oceanography, atmosphere mesoscale and smaller dynamics, air-sea exchanges and biogeochemistry.

### II.3 – Overall time-line of the cruise

We will reach from Bridgetown Harbour, Barbados, heading south-southeast, the northernmost extremity of the nearest antcyclonic eddy (which we will call A1, Fig. II.6), which is, in general, about 200 - 500 km south of Barbados. As we approach the vortex, we will deploy both gliders. Then, from the northern end of the vortex A1 we will carry out a meridian radial of the structure by deploying the CTDs every 10 km and, during the journey between the stations, we will also carry out 1 MVP profile. Then we will perform a zonal station of this whirlwind. At the end of this zonal section we will implement the first phase of high-resolution ocean-atmosphere measurements (mesoscale operation) that will last 4 days.

We will then join the nearest cyclonic eddy (C1, Fig. II.6) to carry out, with the same strategy, its sampling. At the end of the two sections, zonal and meridian, of the C1 vortex, we will again implement high-resolution sampling to observe the sub-mesoscale structure near the C1 eddy.

Finally, we will join the third eddy, the anticyclonic eddy A2 (Fig. II.6), generally located further south-south-east than the first anticyclonic eddy A1, in order to complete our observations at the ocean mesoscale with a eddy closer to its source (the Brazilian North Current) and the influence of the Amazon river but also further than A1 (and therefore less affected) by the waters of the Orinoco river.

In the center of the A1 and C1 eddies, we will deploy two Argo floats in each as well as a float between the two structures but outside them.

### II.4 – Maps of the study area

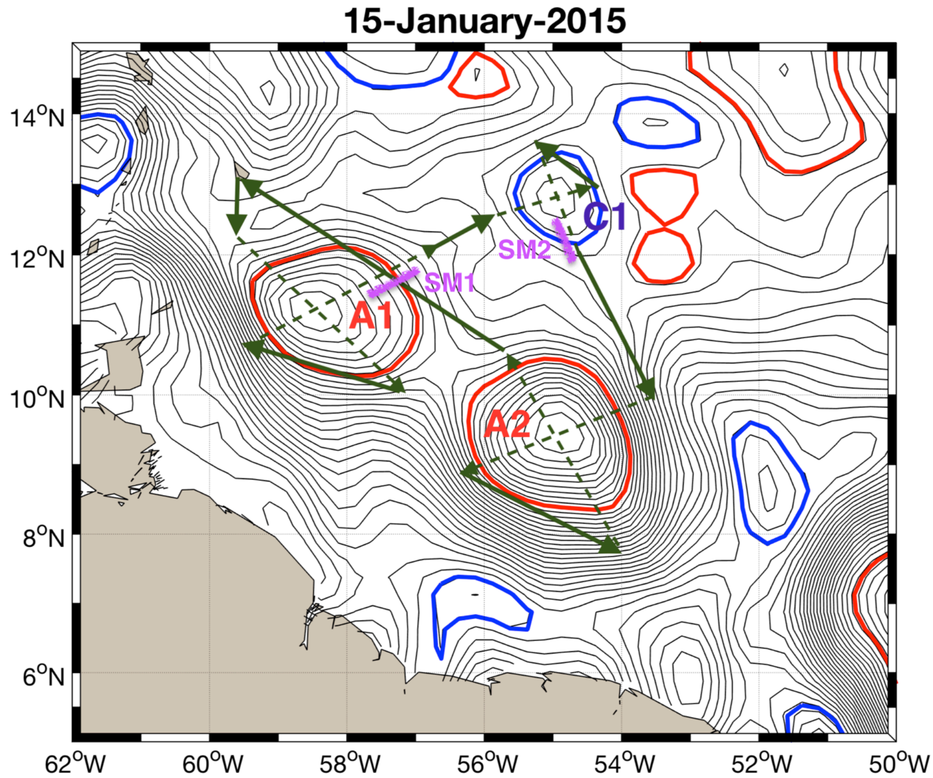


*Figure II.6: Sea surface height (contours) and anticyclonic (red) and cyclonic (blue) contours of ocean mesoscale eddies derived by applying the novel automatic eddy-tracking method of Laxenaire et al. (2018a) for 15 January 2015. The continuous green lines represent the vessel's transits. The discontinuous green lines, CTD sections with stations 10 km apart from each other. The pink lines represent the intensive measurement regions dedicated to the observation of the ocean sub-mesoscale. In the center of the vortices A1 and C1 we will deploy two Argo floats as well as between the two structures.*

## II.5 – Calendar

A meeting in December 2018 will take place during the AGU Fall meeting in Washington DC (USA) to organize the overall EUREC$^4$A-EUREC$^4$A_OA-EUREC$^4$A++-ATOMIC coordinated strategies for the ocean and atmosphere campaigns and sampling and analyses. To these meeting, regular meetings will follow by webex and in person (at the EGU 2019 meeting) to refine the coordinated strategies. In October 2019 we will launch the operational phase of the overall project with a detailed weekly description of ocean mesoscale and atmosphere states.

A first EUREC$^4$A-OA internal meeting will be held in early 2019 (depending on LEFE funding) in Paris and adjustments regarding the precise strategy of the sampling will be rediscussed. Regular meetings to organize and synchronize all the cruise preparations will follow. The intense operational phase will start one month prior to the cruise by daily analyses of the occurring eddies in the large EUREC$^4$A region to help the global strategy for the full international project. Concerning EUREC$^4$A-OA, we will develop the most scientifically and operational tracking of eddies to insure the success of the operations at sea in our region of study, south of Barbados.

During the cruise, frequent scientific meetings will be organized to follow the cruise progress and present the preliminary results. A first post-cruise meeting will be organized roughly 10 months after the cruise in order to present the first results, to help their interpretation and to plan publications. One year later, towards the end of the project, a final meeting will be held to finalize the last results and to ensure that all the available results have been transferred to the different databases. In between, different meetings can be held through videoconferencing device in order to refine interpretations amongst sub-groups.

## II.6 – Publications, outreach and capacity building

**A web site will be developed from the beginning of the project and updated all along.** A special issue will be proposed and organized if accepted. A specific session focused on the « Ocean mesoscale eddies and air-sea interactions in the tropical ocean » will be proposed at an international conference (e.g. Ocean Science meeting 2022, Goldschmidt, EGU and AGU conferences in 2023 and after).

PhD students and postdocs will participate to the cruise.

In total, we anticipate at least 9 PhD subjects to be associated with EUREC$^4$A-OA (2 at LMD, 2 at LOCEAN, 1 or 2 at LOPS, 2 at LEGOS, 2 at MétéoFrance, 1 at LOMIC), and three postdocs.

Outreach activity are planned and will be developed just before, during, and just after the cruise.

# EUREC⁴A-Ocean Atmosphere (EUREC⁴A-OA)

## DATA ANALYSES

### IV. 1. Observed parameters and methods

In the following, we provide a brief description of the scientific contributions and observational approaches of the partners and their working groups involved in this study:

- CTD-O2 water sampling rosette (CTD/RO): The mesoscale CTD hydrographic survey will be carried out along three x-shaped transects. Profiling and water sampling will be performed using a Seabird 911+ system mounted to a rosette with 24 bottles. The CTD-O2 has a double sensor configuration. A backup system will be on board during the cruise.
- MVP300 (or MVP200): An AML Moving Vessel Profiler CTD will be used to acquire research grade CTD profiles while underway at full cruising speed or lower speed for the submesoscale observing periods. The freefall profiler offers vertical profiles from a moving platform. Its deployment winch and re-spooling mechanism allows the probe to be recovered and re-launched time after time without needing to stop or slow down the vessel. CTD section can thus be acquired in a time-efficient manner and at excellent spatial resolution.
- Velocity observations: Shipboard observations of current velocity will be carried out continuously throughout the cruise by shipboard Acoustic Doppler Current Profiler (ADCP). The R/V L'Atalante is equipped with 38 kHz and 75 kHz Ocean Surveyors that allow measurement of current velocity in the upper 1200 m of the water column.
- Microstructure observations: A Vertical Microstructure Profiler (VMP 250) from Rockland Scientific will be used to quantify turbulence in the water column during the mesoscale eddy survey and during the submesoscale process studies. The profiler samples microstructure shear and temperature, oxygen (response time of 0.3s) and turbidity, and is equipped with standard CTD sensors.
- Glider observations: To survey both, the 3D structure of one of the anticyclonic eddy and the sub-mesoscale features, gliders capable of autonomously measuring temperature, salinity, depth, oxygen will be employed.
- Discrete water sampling: On all CTD-O2 stations, water samples from the upper 1500 m (2000 m for Argo DO deployment stations or 3500 m for Deep Argo DO deployment stations) will be analyzed for nutrient content (NO3-, NO2-, NH4+, PO43-) by employing proven wet-chemistry methods. Salinity and oxygen analysis will be used to calibrate the CTD sensors. The CTD-O2 transects across the eddies will be extended beyond the frontal zone to allow eddy waters to be contrasted with the background situation outside the eddies.
- Argo DO Profiling floats: We will deploy 5 Argo floats with Dissolved Oxygen (DO) sensor. We will deploy 2 floats in the center of the first sampled anticyclonic eddy and a second one in the center of the cyclonic center, the fith one in between eddies to contrast the environment from eddies properties. DO profiles strongly complement T-S data, as they will help track the different water masses from the North and South Atlantic Oceans. Also, near the surface, they will be interesting tracers of ventilation, and better documents the interactions near the eddies (horizontal mixing, subduction/obduction and/or freshwater tracking). DO data will be collected from semi-continuous profiling across eddies, as well as during CTD casts. We also hope that gliders will provide complementary DO data. The Argo-DO floats (PROVOR CTS3-DO) will provide important semi-Lagrangian data during the cruise (with fast daily profiling and parking depth in the central water layer) which will be very valuable in near-real time to characterize the structures of eddies and water masses and in delayed-mode to better understand the complicated mixing processes (horizontal between eddy structures, and vertical with variation in particular of the wind forcing and cumulus organization in the trade winds, which is a key component of this project). For the longer term, after the cruise, the Argo floats will be parked at 1000-m and continue profiling on a standard 10-day cycle from 2000 m of depth. We expect them to explore a region of strong meridional transition between the North and South Atlantic which has not been much explored by Argo-DO floats (notice that it is possible with the rather shallow initial parking depth that some floats will be exported through the Caribbean seas, although we do not expect that to be the main fate of the floats).
- Ceilometer / cloud camera: The combination of these instruments provide detailed information of clouds. The ceilometer offers a more accurate cloudbase altitude estimate and a thermal cloud camera extends spatial coverage. Cloud detail statistics is complement by similar measurements on other EUREC4A implicated ships and at the Barbados site.
- Radiosondes: frequent radiosondes (4/day during mesoscale sampling and 8/day during the submesoscale enhanced observing periods) will provide atmospheric state with higher altitude data (up into the stratosphere). Radiosonde launches on this ship are complemented by radiosondes launches on other ships and at the Barbados Station site as well as dropsondes (from the air-planes) so that larger scale vertical movements of atmospheric can be derived.

- Rain gages: these instruments measure the precipitation that reaches the ground. As precipitation is extremely sparse many samples, much more than can be sampled during EUREC⁴A-OA, are needed for reliable statistics. Still events with precipitation in terms of clouds and environmental properties are of interest.
- Broadband Radiation Downwelling broadband solar and infrared measurements, which provide combined information on atmospheric properties, are part of the atmospheric observing equipment
- Meteorological mast: A mast equipped to provide direct estimate of turbulent sensible and latent (evaporation) heat fluxes by eddy covariance technique will be installed at the bow of the ship. These observations are critical to monitor the atmospheric boundary layer turbulence characteristics. These observations, complemented with ship based surface meteorology parameters, skin (Infrared sensor) and 4m-depth temperature (ship Thermosalinograph) and measurements of shortwave and longwave radiative fluxes at the surface are fundamental to diagnose the energy exchanges between the atmosphere and the ocean.
- Air-Sea Turbulent and Radiation fluxes: Two prototypes of drifting buoys from the MIO laboratory (OCARINA and PICCOLO) will provide estimates of air-sea turbulent and radiation fluxes, as well as measurements of the wind profiles in the first meter above the surface, of swell characteristics (period and significant height), and of sea surface temperature and salinity. These buoys will be deployed for 10 to 20-hour time periods from the French research vessel, which will simultaneously perform redundant measurements of air-sea fluxes.
- A PICARRO LRDS analyzer will be provided by LOCEAN to analyze the isotopic composition of water vapor ($d^{18}O$ and dD). These data will provide insights on the water vapor origin, in particular whether it results from evaporation from the surface or is transported downward from the cloud layer or above (Benetti et al., 2015, 2016). Such an instrument (from ETH) will also be deployed on the ATR42, as well as on Barbados (at BCO). It is very important to get another instrument at the sea level and upstream of BCO and of the sampling area of the ATR42 to correctly interpret the airborne and ground-based measurements.

### IV. 2. On board data analyses and processing

Physical parameters:

- Salinity and dissolved oxygen: will be analyzed on board using a salinometer (provided by our south African colleagues) and a winkler titration method, respectively.
- Water velocity: will be acquired onboard by the Ship Acoustic Doppler Current Profilers (SADCP) mounted in the hull and will be measured down to the bottom on station by 2 LADCP mounted on the rosette).

Ancillary parameters:

- Partial pressure of carbon dioxide (pCO2): This variable of carbonic system will be measured underway with an automatic pCO2 system. Briefly, seawater is flowing through an thermostated interface that provides an equilibrated gas sample to the detector, before being analysed by infra red method (NDIR, Siemens Ultramat 5F). External validation is performed three to four times a day (reference gas at 270, 350 et 480 ppm) . After data processing of SST and salinity, fCO2 measurements are corrected following Weiss and Price (1980) and Copin-Montégut (1988, 1989) polynomial equations. Precision of this method is estimated to be +/- 0.7 µatm.
- We will try to analyse Nutrients on board (otherwise it will be ad hoc sampled stored in freezer) . The on board analyses, if they take place, are as follow. Silicates and nitrates will be analysed by standards methods with a Bran+Luebbe AAIII autoanalyser. Phosphates samples will be analysed using a manual spectrophotometer «Shimatzu UV 1700».

### IV. 3. Data acquisition during the campaign

The acquisition of "ship" data (navigation, weather, sounding) is the responsibility of IFREMER and its on-board IT team.

Data acquisition is the responsibility of the teams during the campaign.

An exhaustive description of the methods, type and number of data acquired during the campaign will be carried out at the end of the mission under the responsibility of the heads of mission with the help of P. Bouruet-Aubertot for Physics. This will serve as a framework for setting up a file database and its catalogue.

### IV. 4. Data processing and pubblication

Data processing is the responsibility of the teams during one year after the cruise completion.

First results should be available 6 months after the completion of the cruise, as well as a full cruise report. Then a post-cruise meeting will be organized in order to discuss the available data. First publications could be published one year after the cruise completion. 18 months after the cruise completion, another post-cruise meeting should be held, allowing more data to be shared and discussed. At this time, plan for a special issue will be determined.

### IV. 5. Data bases and dissemination

The underway ocean-surface and atmospheric data will be immediiately realeased via the GTS system to be integrated daily to the weather and ocean forecasts systems..

After validation the ocean data will be transferred by the teams that acquired and processed them in the form of electronic files to the "SISMER" database in Plouzané (France) and those concerning the atmosphere to the French atmospheric data pole AERIS.

We will also integrate all of them in the specific « EUREC4A » data base that will be hosted at the IPSL cluster for dataset to be discussed and used in collaborative works among the different national and international partners of the larger EUREC4A action.

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# An International Initiative for the Tropical Ocean-Atmosphere Interactions at the Ocean Mesoscale

## The US (ATOMIC) and European (EUREC$^4$A-OA) components


**ATOMIC** *Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign*
**USA:** C.W. Fairall, P. Zuidema, K. Emanuel, M. Zhao, R. C. Perez, S. Bigorre, Chidong Zhang, J. Thomson, R. Pincus, J. Olson, G. Feingold, C-A Clayson, S. de Szoeke, Jerome Schmidt

**EUREC$^4$A-OA** *EUREC$^4$A Ocean & Atmosphere component*
**France:** S. Speich, H. Bellanger, G. Reverdin, S. Bony, B. Deremble, J.-L. Dufresne, F. Hourdin, I. Musat, C. Muller, R. Vogel, F. Beucher, D. Bouniol, F. Burnet, G. Canut, F. Couvreux, C. Denjean, G. Faure, H. Giordani, R. Honnert, C. Lac, G. Roberts, R. Roehrig

**Germany :** J. Karstensen, M. Dengler, W. Mohr, F. Ament, G. Bagheri , E. Bodenschatz, S. Buehler, S. Crewell, C. Klepp, S. Gross., C. Hohenegger, S. Kinne, D. Klocke, P. Landschützer, AK Naumann, M. Pöhlker, B. Mayer, M. Sakradzija, B. Stevens M. Wendisch, H. Kalesse

**Other EU partners:** L. Nuijens and P. Siebesma (U Delft), I. Sandu (ECMWF), S. Malinowski (U. Warsaw), M. Jochem (Niels Bohr Institute). A. Blyth (Leeds), B. Webber (E.Anglia), J. Piskozub (Sopot, PO)

## 1. **Introduction**

The atmosphere and ocean drive processes in one another through air-sea interaction mechanisms– primarily mixing in turbulent boundary layers. Above most of the oceans, liquid clouds of a few thousand meters or less mix the lower atmosphere in a process called shallow convection. The warm cloud types dominate coverage of the ocean and may strongly influence weather on seasonal to sub-seasonal time scales. Indeed, deep and shallow convection are intricately linked, with shallow convection acting to humidify the lower troposphere and create conditions in which deep convection can arise. Shallow convection exerts an important influence on sea surface temperatures (SSTs) and salinity by moderating the air-sea exchanges of energy and moisture. For global prediction models in the foreseeable future, shallow convection is a "grey-zone" problem in which the circulations are too small to be represented explicitly, but too large and too few to be represented with the equilibrium statistical approaches required for parameterization. The issue stems not from the scale of individual clouds but rather of the mesoscale circulations that organize the shallow convection, producing a large range of cloud morphologies that affect radiative fluxes and possibly precipitation at the surface.

The interaction between shallow convection and the ocean's surface layers is a two-way street: though shallow convection influences SSTs, it is itself controlled to a large extent by SST and air-sea fluxes, which are mediated by processes within the ocean, especially Oceanic Barrier Layers (OBL) and mesoscale ocean eddies. OBL are near-surface layers created by low salinity waters and embedded in the ocean mixed layer. OBLs tend to decouple the ocean mixed layer from momentum fluxes but also may drive subsurface warming through facilitating the penetration of short wave radiation to the base of the OBL. In doing so, the OBL can influence weather and climate patterns. The OBL in the tropical northwest Atlantic are some of the thickest in the world (Mignot et al. 2007); unlike other OBL in central regions of the tropical oceans, they are also persistent over most of the year and are accompanied by warm anomalies below the OBL that are still within the ocean mixed layer. This subsurface reservoir of heat can have a strong effect on hurricane intensification (Balaguru et al., 2012 *PNAS*), whereby wind stirring causes the upper ocean to warm up, as opposed to the cold oceanic wakes that usually accompany hurricanes. On the other hand, if the subsurface heat anomaly associated with OBL is not re-exposed to the atmosphere, then the question arises as to the effect of a net heat export into the ocean interior, and its relevance to climate.

Ocean mesoscale eddies are another mechanism that strongly affect the ocean surface heat budget and therefore SST. They are ubiquitous in the ocean (Chelton et al., 2011 *Progr. Oceanogr.*). There is increasing evidence, mostly from observations in the extra-tropics, that dynamical processes associated with mesoscale ocean eddies drive SST anomalies which in turn impact the air-sea exchanges and the overlying atmosphere (wind, clouds, rainfall, Frenger et al. 2013 *Nat. Geosci.*; Villa Boas et al. 2015 *Geophys. Res. Lett., Ma et al. 2016, Nature, DOI 10.1038/nature18640.*). Preliminary results suggest it is also the case in the tropics (MS Thesis of Léa Olivier, LMD-ENS). This topic is gathering high interest in the scientific community; air-sea interactions at the scale of ocean eddies were the theme of a recently organized CLIVAR workshop co-chaired by S. Speich (www.clivar.org/events/ocean-mesoscale-eddy-interactions-atmosphere-workshop). Preliminary results from satellite and in-situ data show that in the Tropical Northwest Atlantic, ocean eddies are massive heat reservoirs that capture the fresh waters of the Amazon and Orinoco rivers. These regional OBL hotspots are efficient heat and humidity sources for the atmosphere. However, the exact genesis, properties and fate of the regional mesoscale ocean eddies, as well as their precise influence on Tropical Northwest Atlantic air-sea interactions, surface energy budgets, and atmosphere shallow convection is still poorly known.

Better understanding of the coupling of the ocean and atmosphere offers the opportunity to improve seasonal to inter-seasonal predictions by alleviating errors in modeling the coupled ocean-atmosphere system. Those errors might arise one of four sources: 1) inaccurate representation of the transfer of moisture, energy, and momentum from the atmospheric boundary layer to the free atmosphere; 2) errors in representing the coupling of the atmospheric boundary layer to the ocean surface layer; 3) neglecting the meso-scale circulations which organize shallow convective circulations in the atmosphere and influence the distribution of cloud properties, and 4) errors in representing ocean properties, such as OBLs, which strongly influence SSTs.

The **Atlantic Tradewind Ocean-Atmosphere Mesoscale Interaction Campaign** (**ATOMIC, US)** and the **Ocean-Atmosphere** component of **EUREC$^4$A** (**EUREC$^4$A-OA, Europe)** initiatives will take advantage of the complementary existing international EUREC$^4$A intensive atmospheric field campaigns taking place during 6 weeks in January-February 2020 **to address the Northwest Tropical Atlantic Ocean-atmosphere interactions at the mesoscale and their relation to the regional OBL, air-sea interactions and atmospheric shallow-convection.**

## 2. The ATOMIC and EUREC$^4$A-OA components

The international field campaign named EUREC$^4$A (Elucidating the role of clouds-circulation coupling in climate) will take place from 20 Jan to 20 Feb 2020 over the Northwest Tropical Atlantic, near Barbados (Bony et al. 2017 *Surv. Geophys.*, www.eurec4a.eu). EUREC$^4$A, which has been endorsed by the World

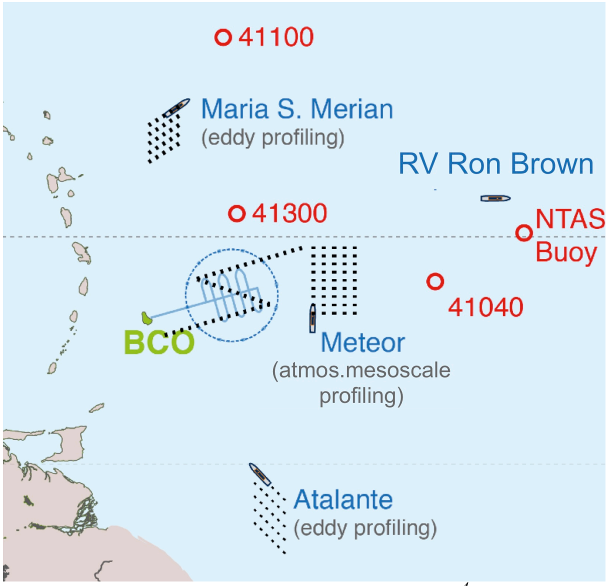


*Figure 1. Observation strategy for the EUREC$^4$A core campaign. BCO denotes the Barbados Cloud Observatory. EUREC4A aircraft operations (race track and circle traces) will be conducted from Barbados. Red number denote NOAA buoys. Ship locations are approximate. Rawinsondes will be launched from the ships and BCO.*

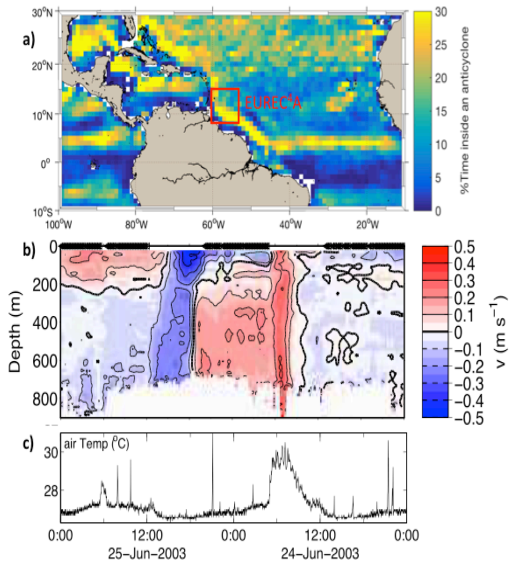


*Figure 2. (a) Percentage of presence of ocean mesoscale anticyclonic eddies (Laxenaire et al. 2018, JGR) derived from satellite altimetry. The red box shows the EUREC$^4$A region, (b) meridional current profiles (black segments at 0m when the ship is not moving) and (c) air temperature taken during a survey through an anticyclonic eddy west of Barbados (SO172 campaign). The eddy was associated with air temperature perturbation >2°C, (for clarity time axis is reversed as the ship was cruising to the west).*

Climate Research Program (WCRP) is designed to test critical hypotheses related to the interplay between clouds, (atmospheric) convection and circulations, and their role in climate sensitivity. It will in particular focus on the shallow marine cumulus prevalent over the world's trade-wind belts and tropical oceans. Cloud sensitivity to changing environmental conditions has the potential to strongly influence the evolution of future climate warming. EUREC$^4$A's core measurements come from two well-equipped research aircrafts (the French ATR-42 and German HALO, Fig. 1), includes a dense network of atmospheric soundings from HALO dropsondes, and land-based instrumentation from the Barbados Cloud Observatory. The plan for intensive atmospheric observations during EUREC$^4$A, and the international momentum and cooperation associated with it, are opportunities for complementary investigations to better understand air-sea interactions, and interactions between the atmosphere and ocean boundary layers, shallow cumulus clouds, tropospheric water vapor in the North Tropical Atlantic.

The **ATOMIC & EUREC$^4$A-OA** teams propose to take advantage of EUREC$^4$A to address complementary aspects albeit key for the complete understanding of shallow-convection processes in the Tropical Atlantic. The **ATOMIC & EUREC$^4$A-OA** projects will complement EUREC$^4$A by focusing on the air-sea exchange and connecting it to the processes above and below the material surface of the ocean. The atmospheric work will focus on the processes associated with shallow convection – vertical mixing by clouds and turbulence, cloud-radiative coupling, the role of precipitation how shallow convective transport of scalars and momentum affect the local and regional structure of the marine boundary layer and how the shallow cumuli affect the oceanic surface energy budget. The oceanic work will focus on the role of eddies, barrier layers, and surface forcing on oceanic boundary-layer mixing. The oceanic work will benefit from and require the unprecedented surface forcing information provided by the large scale atmospheric array and from direct flux observations from ships.

The **ATOMIC & EUREC$^4$A-OA** program will feature a two-month field observation period combined with extensive process-level modeling with linkages to operational Numerical Weather Predictions (NWP) centers and climate model centers. Indeed, EUREC$^4$A's construction, based on two research aircrafts, one hosting remote sensing instrumentation at high-altitude, launching dropsondes from a circular flight path towards determining the atmospheric vertical velocity profile, with a second aircraft making low-altitude surface flux and microphysical measurements (Fig. 1). The aircraft dropsonde and ship upsonde data will be assimilated to provide re-analysis field of large scale and mesoscale forcing. The **ATOMIC & EUREC$^4$A-OA** will add airborne and shipborne observing systems that complement EUREC$^4$A. The shipborne observations will focus on continuous time series profiling in contrast to the airborne spatial snapshots planned by EUREC$^4$A.

In particular, **ATOMIC & EUREC$^4$A-OA** will focus on **(A) tropical ocean-atmosphere interactions at the ocean mesoscale (10-500 km), and assess the impact of the air-sea coupling on both the ocean and atmosphere at this spatial scale**, and **(B) the multi-scale modeling of the atmosphere and of ocean-atmosphere coupling**. For this purpose, **ATOMIC & EUREC$^4$A-OA** teams propose:

**(A)** To lead oceanographic and ship-based atmospheric measurements and deploy innovative automated devices (gliders and drones) towards characterizing the variability of oceanic and atmospheric properties at the mesoscale, and to deploy a ship-based network of radiosondes to characterize the atmosphere variability on the diurnal time scale and on a spatial scale larger than the area of aircraft operations;

**(B)** To promote a coordinated global analysis of EUREC$^4$A and **ATOMIC & EUREC$^4$A-OA** observations and modeling that will advance the understanding of cloud-circulation and morphology and how the ocean-atmosphere couplings produce transitions of the boundary layer structure across the edge of the mesoscale eddies, and make use of these observations to improve the weather and climate models.

**The US and European Programs to Study Tropical Atlantic ocean-atmosphere interactions at the mesoscale (ATOMIC & EUREC$^4$A-OA)** will offer the unique and unprecedented opportunity to extensively observe such interaction in the Tropics with in situ measurements. Indeed, the EUREC$^4$A region is one pathway of numerous mesoscale eddies originating from the near-equatorial Atlantic Ocean and along the Brazilian coast (Fig. 2a). This region is also characterized by fresh surface water influenced by South-American river run-off that leads to the frequent formation of OBL. The interplay between eddies and this particular vertical structure results in complex mesoscale variability at the ocean surface that has a strong signature in sea surface temperature (SST), surface salinity (visible satellite), and air temperature fields (Fig. 2bc). The eddies will impact the atmosphere through their surface fluxes, which in turn can affect the shallow cloud fields and their organization, but the strength of this connection is not yet known. Only a synergy between intense and comprehensive ocean-atmosphere observations and modeling can help advance this knowledge.

Moreover, the exchange of carbon dioxide ($CO_2$) between the atmosphere and the ocean is driven by their CO2 concentration or partial pressure difference at the interface. Globally, this difference is mainly driven by the ocean side with the ocean circulation playing a major role in the exchange of mass between the spheres. While the large-scale effect of circulation and mixing on the exchange of $CO_2$ between the ocean and the atmosphere is well understood, much less is known at smaller scales. Locally, studies have shown that ocean eddies strongly contribute to the vertical transfer of surface properties, yet the resulting effect on the exchange of $CO_2$ has not been fully quantified. Here, we propose to investigate the exchange of $CO_2$ between the atmosphere and the ocean in an ocean eddy environment. In the proposed experiment, we will monitor both the ocean and atmospheric $CO_2$ partial pressure as well as environmental variables such as SST, sea surface salinity, surface wind, current structure, and surface air pressure, while systematically navigating through mesoscale ocean eddies of different origins and surface signature. The study aims to provide a better understanding to what extend eddy driven transport and mixing of oceanic water masses enhances the local air-sea exchange of $CO_2$.

These are the objectives of the combined and coordinated US-European **ATOMIC & EUREC⁴A-OA**.

## (A) Observing the tropical ocean-atmosphere interactions at the ocean mesoscale

The strategy chosen for the **ATOMIC & EUREC$^4$A-OA** campaigns is a 1.5/2-month cruises with different ships (the German R/Vs *Meteor* and *Maria S. Merian*, the French *Atalante*, and the US-NOAA R/V *Ronald H. Brown*), complementing planned one month depoloyments of the German HALO (G550) and French ATR-42 aircraft, and extensive and expanded ground based measurements from Deebles and Ragged Points on Barbados. Additional requests are pending for research aircraft (including the US-NOAA G-4 and P-3 aircraft, the ONR Twin Otter, the BAE-146, a NASA and European Aircraft for wind-measurements) and the deployment of different additional observing equipment such as the Boreal drone, Saildrones, and SLOCUM and Oculus gliders complementing the intensive atmospheric and oceanic measurements of the core EUREC$^4$A campaign. The ship cruise will involve both station observation to monitor the large-scale environment periods and surveys of selected eddies.

- The Boreal drone will help to understand how the ocean and the atmosphere interact at the mesoscale and to unravel the physical mechanisms controlling the mesoscale organization of the atmospheric boundary layer. The Boreal drone (endurance of 10h/1000 km, Robert et al. 2017 *La Météorologie*) will be launched from Barbados island and during the ATR42/HALO flights to map SST, sea state and the surface energy and aerosol fluxes, and meteorological parameters near the ocean surface and to quantify ocean-atmosphere interactions on scales of several hundred km within the EURAC$^4$A study region.
- The international fleet of ships will survey intensely different mesoscale ocean structures whose position will be known precisely via an automated remote sensing eddy detection developed at LMD and applied on near-real time. The US-NOAA ship R/V *Ronald H. Brown* will be positioned near the NTAS permanent station (Fig. 1). The German ship *Meteor* will be positioned over the main areas of flight operations. The French and second German ship will be positioned in a manner to best ample the southern pathway of mesoscale eddies and fully cover the EUREC$^4$A domain. These surveys will be carried out using autonomous gliders with attached turbulence probes (independent from ships) in addition to ship based high-resolution CTD, RapidCAST, XBTs, ADCP current and turbulence profiles, and underway observations of atmospheric and oceanic parameters including ocean currents.
- Saildrones will measure air-sea fluxes of latent and sensible heat and radiation, surface and upper ocean temperature and salinity to fill the gaps between stationary ships. Saildrones can stay in water for six months to provide a seasonal context for the field campaign.
- Station locations will be set in accordance with other EUREC$^4$A oceanographic campaigns to form a radiosonde network (with up to eight soundings per day) in a region encompassing the core experiment area. This network will be used to derive a continuous temporal evolution (resolving the diurnal cycle) of the large-scale synoptic circulation and of the apparent heat source and moisture sink around the periods of the core experiment flights. This will also result in better meteorological analysis in the region by the real-time assimilation of EUREC$^4$A-OA observation by operational centers. For these purposes coordination with the ECMWF is already underway.

## (B) Multi-scale modeling the tropical Atlantic ocean-atmosphere coupled system

EUREC$^4$A and **ATOMIC & EUREC$^4$A-OA** will provide an unprecedented dense network of co-localized observations of the atmosphere and of the ocean in the trade-wind regime that will benefit the modeling community. At the international level (GEWEX GASS), EUREC$^4$A has been proposed as an opportunity for the second phase of the intercomparison of models on the grey zone (resolutions between 100 m to 10 km where boundary layer and convective processes are partially resolved and parameterized). These joint modeling activities involve a hierarchy of models from Large Eddy Simulation (LES), or multi-resolution approaches using ICON, to NWP regional (operational like ICON, AROME *Outre-Mer* or research models like Meso-NH and WRF-ARW) and global (e.g. ICON, LMDz, ARPEGE, IFS, and FV3) models. **ATOMIC & EUREC$^4$A-OA** modeling activities will aim at improving our understanding not only of the impact of the ocean mesoscale eddies on air-sea coupling and the atmospheric boundary layer but more generally of shallow convection and clouds in the trade-wind regimes and the underlying mechanisms and radiative impact of the mesoscale atmospheric organization. They ultimately aim at improving the physical parameterizations of NWP and climate models, and to facilitate development of coupled ocean-atmosphere cloud and eddy-resolving models.

## 3. Duration

The field program will be approximately two months in the January-March 2020 time frame, with the central measurement period being between 20 January and 20 February. The project will be 4 years beginning in 2019.

## 4. Relevance to CLIVAR's present activities

EUREC$^4$A has been endorsed by the World Climate Research Program (WCRP). It is of major relevance for WCRP related activities (including CLIVAR and GEWEX). **ATOMIC** & **EUREC$^4$A-OA** are directly and/or indirectly related to numerous CLIVAR goals and activities, including CLIVAR's regional panels (e.g., Atlantic, Northern and Southern Ocean Implementation Panels), all the CLIVAR's global panels (Global Synthesis and Observations Panel – GSOP, Ocean Model Development Panel – OMDP, the Climate Dynamics Panel – CDP, and the CLIVAR/GEWEX Monsoons Panel), several Research Foci (Decadal climate variability and predictability – DCVP, Consistency between planetary energy balance and ocean heat storage– CONCEPT-HEAT, Understanding and predicting weather and climate extremes, ENSO in a changing Climate), and several endorsed projects (e.g., TACE, PIRATA, IASCLIP, CLIVAR Repeat Hydrography), and major activities (e.g., Atlantic Meridional Overturning Circulation – AMOC, including RAPID-MOCHA and SAMOC). CLIVAR has just started to explore possibilities for an initiative on mesoscale oceanic eddies (www.clivar.org/events/ocean-mesoscale-eddy-interactions-atmosphere-workshop). Data collected in **ATOMIC** & **EUREC$^4$A-OA** will help in the understanding of processes responsible of the ocean mass and meridional heat transport and property fluxes for the CLIVAR Repeat Hydrography program, as well as air-sea heat exchange calculations needed to meet the western hemisphere warm pool prediction goals of IASCLIP. Clearly **ATOMIC** & **EUREC$^4$A-OA** will be an important element to consider the future Tropical Atlantic Observing System (TAOS).

## 5. Broader impacts and benefits of the proposed activity

The **ATOMIC** & **EUREC$^4$A-OA** measurements set the context for a yet more ambitious effort to build on the EUREC$^4$A measurements and by so doing to provide a benchmark data set for constraining a new generation of coupled models capable of resolving convective heat transport in the atmosphere, and meso- to sub-mesoscale variability in the ocean. This large internationally coordinated project will also advance our understanding of the coupled system at the ocean mesoscale, and mesoscale oceanography in its own right, including also ocean biogeochemical and biological processes. Improved knowledge and model representations of the interaction of cumulus clouds with the atmospheric and oceanic boundary layers resulting from ATOMIC and EUREC4A-OA, have the potential to tap unrealized predictability in the climate system and thereby improve seasonal to subseasonal weather and climate prediction. Improved representation of the cumulus cloud ensemble constrains regional and global cloud and tropospheric water vapor climate feedbacks, which in turn constrains projections of both global climate, and the hydrological response of rainfall, its spatial distribution, and its extremes in a changed climate.

Moreover, each of the ships will be equipped with active remote sensing (e.g. Radar and Lidar - similar to instruments at the Barbados Cloud Observatory site and on the HALO and ATR-42 aircraft). This also makes this campaign very attractive for space-agencies (e.g. ESA: ADM-Aeolus, EarthCARE, Sentinel; NASA: MODIS, VIIRS) for reference data to evaluate and improve their retrieval models (e.g. in support of the EarthCARE mission, the German EarthCARE office is at the MPI-M).

## 6. The International Consortium

### ❖ International collaborations

- EUREC$^4$A originated as a French-German initiative led by S. Bony and B. Stevens, Bony et al. 2017, building on ongoing measurements made at and around the Barbados Cloud Observatory whose aim is to better understand cloud controlling factors in the trades It currently involves many French (LMD, LATMOS, LSCE, LAMP, SAFIRE,) and Germany (three to four Max Planck Institutes, GEOMAR, DWD, DLR, Universities in Hamburg, Leipzig, Cologne and Munich) partners as well as many other institutions in Europe (ECMWF, U. of Leeds, KNMI, U. of Delft, Univ of Warsaw, East Anglia, and the Niels Bohr Institute) and in the US (NOAA, MIT, WHOI, NASA). EUREC$^4$A, which has become a capstone field experiment in support of the WCRP Grand Challenge on *Clouds, Circulation and Climate Sensitivity* (Bony et al., *Nature Geosci.,* 2015), is discussed every year at the WCRP JSC, and connects to several WCRP core projects: GEWEX (several white papers for joint modeling activities related to EUREC$^4$A have been discussed at the last GEWEX Pan-GASS conference in Australia in Feb 2018) and CLIVAR (EUREC$^4$A has been discussed at the CLIVAR Atlantic Regional Panel, at the kickoff workshop for the tropical Atlantic Observing System review and at the Ocean mesoscale eddies and air-sea interactions workshop in Portland, USA, Feb 2018).

- In Germany, MPI for Meteorology, MPI for Marine Microbiology, GEOMAR, the MPI for Dynamics and Self Organizatio, the Universität Hamburg in coordination with University Partners throughout Germany (Leipzig, Cologne, Munich) have submitted a proposal for the deployment of 2 Research Vessels (*Meteor* and *Merian*) during EUREC$^4$A; the deployment of one of them (*Meteor*) has already been accepted (Mar 2018), with a recommendation to submit a revised proposal for the second ship This second proposal is in the process of submission and the decision regarding the second ship will be made by the end of the summer. The ship measurements complement aircraft measurements using HALO (the German high-altitude and long-range research aircraft) which is funded by the Max Planck Society, the German Research Foundation (DFG) and the DLR. Also the DLR polarized C-Band radar PoliRad will deployed at an elevated ground site on Barbados as part of EUREC$^4$A.

- There is strong participation and support for EUREC$^4$A, especially through the ground based measurements at Deebls and Ragged Points on Barbados, from the Caribbean Institute of Meteorology and Hydrology (D. Farrell and M. Forde)

- As an extension to EUREC$^4$A, EUREC$^4$A-Wind (L. Nuijens Deflt) proposes to Cal/Val measurements of the soon to be launched AEOLUS satellite, and to study the role of moist convection in momentum transport as part of the ERC funded Cloud-Brake project. It is anticipated that one to three aircraft (DLR or French Falcon, and a NASA aircraft), with advanced wind-lidar capabilities, will join the EUREC$^4$A campaign as part of EUREC$^4$A-Wind.

- In France support for a French research aircraft (the ATR-42) has been secured for airborne operations in the core EUREC$^4$A field study, and a letter of intent for the support of shipboard measurements has been submitted.

- In the US, the deployment of the NOAA ship *Ronald H. Brown* and NOAA aircraft P-3 and G-4 is pending (Atlantic Trade-Wind Ocean-Atmosphere Mesoscale Interaction Campaign -ATOMIC- proposal, C. Fairall). At NASA (D. Winker), a proposal for the deployment of the P3 aircraft (with wind and water vapor lidars on board) is pending. University-based researchers will coordinate on proposals to NSF to support participation and analysis.

- In the UK, a proposal (EUREC$^4$A-UK) has been submitted by the U. of Leeds (led by Alan Blyth) to deploy the FAAM aircraft and support the national Paracon project on convection. Likewise, deployment of the ONR twin-otter (Q. Wang, NPS) is planned to support an aerosol-cloud interaction component to EUREC$^4$A.

- **Participants (PIs)**

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- **Financial Implications**

  - ***German Cost Estimates***

The German tam have already obtained the ship time and costs coverage for at least one ship (R/V *Meteor*). The availability of the R/V *Merian* is still pending. The cost of data validation, calibration and analyses will be covered by in-kind sources (GEOMAR and Max-Plank Institute of Meteorology) and additional external funding. Funding for ground based measurements and at least one aircraft has also been secured; this alone amounts to about 5 M€. Additional funding for the ship deployments, in-kind support for the modeling studies, and subsequent analysis will bring the German contribution to nearer 10 M€.

  - ***US Cost Estimates***

The US team is pursuing an initiative within NOAA to participate in the project. If fully successful, NOAA would provide the R/V *Ronald H. Brown* (30 days, 850* USk$), the G-4 aircraft (120 hrs, 350 dropsondes, 850* USk$), and the P-3 aircraft (120 hrs, 50 dropsondes, 850* USk$). NOAA's Climate Variability (CVP) program and NOAA's Office of Weather and Air Quality (OWAQ) have been approached to offer a request for proposals for NOAA and non-NOAA scientists to participate in ATOMIC. We anticipate that university investigators would also propose to NSF to be involved in the field program or the modeling efforts. To fully utilize the US platforms would require on the order of 3-5 m$/yr for three years of joint NOAA/NSF funding plus 1-2 m$/yr in NOAA's research laboratory funds (including about 0.7 m$ for two month deployment of Saildrones and Oculus gliders).

  - ***French Cost Estimates***

The French EUREC$^4$A team is funded through a European Research Council grant. It has submitted a pre-request of the R/V *Thalassa* or *Atalante* whose availability is still pending. National grant proposals have been and will be submitted in the coming months to INSU-CNRS and ANR to complement the costs for the cruises, additional equipment, data processing and analyses as well as modeling experiments and parameterization studies. Present French funding is in the order of 3 M€.