



CENTRE NATIONAL D'ÉTUDES SPATIALES

PROPOSITION DE RECHERCHE SCIENTIFIQUE SPATIALE

POUR 2016

Le dossier doit être impérativement approuvé par le Directeur du laboratoire proposant. Chaque dossier de proposition doit comporter 3 fichiers portant le même nom : un formulaire MS-word, un formulaire MS-excel et la fiche résumé du formulaire MS-excel signée par le Directeur du laboratoire et scannée au format .pdf.

1. RENSEIGNEMENTS GÉNÉRAUX

1.1. INTITULÉ DE LA PROPOSITION¹

CNES-OUTPACE (Oligotrophy from Ultra-oligoTrophy PACific Experiment)

1.2. SCIENTIFIQUE PROPOSANT

Nom : **Doglioli**
Prénom : Andrea
Téléphone : +33(0)4 86 09 06 08
e-mail : andrea.doglioli@univ-amu.fr
Nom du Laboratoire : **Institut Méditerranéen d'Océanologie (MIO)**
Adresse : Campus de Luminy - Case 901
13288 MARSEILLE cedex 9
France
Organisme de tutelle : Université d'Aix-Marseille (AMU)
Organisme gestionnaire : CNRS

1.3. CO-PROPOSANTS²

Nom : **Petrenko**
Prénom : Anne
Téléphone : +33(0)4 86 09 06 06
e-mail : anne.petrenko@univ-amu.fr
Nom du Laboratoire : **Institut Méditerranéen d'Océanologie (MIO)**
Adresse : Campus de Luminy - Case 901
13288 MARSEILLE cedex 9
France
Organisme de tutelle : Université d'Aix-Marseille (AMU)
Organisme gestionnaire : CNRS

Nom : **Moutin**
Prénom : Thierry
Téléphone : +33(0)4 86 09 05 71
e-mail : thierry.moutin@univ-amu.fr
Nom du Laboratoire : **Institut Méditerranéen d'Océanologie (MIO)**
Adresse : Campus de Luminy - Case 901
13288 MARSEILLE cedex 9
France
Organisme de tutelle : Université d'Aix-Marseille (AMU)
Organisme gestionnaire : CNRS

Nom : **Bonnet**
Prénom : Sophie
Téléphone : + 687 26 07 46
e-mail : sophie.bonnet@univ-amu.fr
Nom du Laboratoire : **Institut Méditerranéen d'Océanologie (MIO)**
Adresse : IRD Noumea 101 Promenade R. Laroque, BP A5
98 848 Nouméa Cedex
Nouvelle Calédonie
Organisme de tutelle : Institut de Recherche pour le Développement (IRD)
Organisme gestionnaire : CNRS

2. PROPOSITIONS NOUVELLES³

2.1. OBJECTIFS SCIENTIFIQUES⁴

2.2. SITUATION ACTUELLE DU THÈME DE RECHERCHE⁵

2.3. DESCRIPTION DÉTAILLÉE DE LA PROPOSITION⁶

2.4. CALENDRIER PRÉVISIONNEL DE LA PROPOSITION⁷

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3. PROJETS ENGAGÉS⁹

3.1. RAPPEL DES OBJECTIFS SCIENTIFIQUES¹⁰

The scientific goals are maintained with respect the ones proposed in the proposal submitted last year. They are summarized below.

OUTPACE project (PIs: T.Moutin and S.Bonnet) aims at studying the functioning and the productivity of the oceanic oligotrophic systems that could **largely contribute to the global ocean organic carbon export** (Karl et al., 2012). The overall objectives of the project are **to provide a zonal description of the biogeochemical functioning and biological diversity of the South West Pacific** along a gradient of macro- and micro-nutrients availability. Therefore, the project proposes a **in situ campaign for a detailed study of the biological production and its subsequent fate in 3 contrasting sites**, with a specific emphasis on the production sustained by nitrogen fixation. Our goal is to determine whether organic matter production, re-mineralization and export processes are different at these sites, and if so, determine how such differences are related with the diversity/function of nitrogen-fixing organisms in the planktonic community. Comparing different sites, along a zonal gradient of differing nutrient availability, will provide a **new insight for identifying and understanding the fundamental interactions between ocean dynamics, marine biogeochemistry and ecosystems**.

At the international level, the OUTPACE project fits into the scientific priorities of the large international programs from IGBP and SCOR (IMBER, SOLAS, GLOBEC) as it aims at acquiring knowledge to understand, quantify and model/forecast interactions between biogeochemical cycles and marines ecosystems. The OUTPACE project received the support of the international IMBER (Integrated Marine Biogeochemistry and Ecosystems Research) program. At the national level, it is founded by ANR, LEFE/CYBER and GMMC, IRD and GOPS.

The CNES-OUTPACE proposal aims at supporting the satellite-based Lagrangian strategy of the OUTPACE cruise.

The specific objectives are:

- i) to guide the adaptive, Lagrangian sampling strategy for in situ process studies on carbon export;
- ii) to provide insights of the spatial and temporal variability of the physical and biogeochemical characteristics of the surrounding waters of the OUTPACE cruise.

This implies an intense use of remote sensing products, that will in addition provide in situ data for satellite cal/val in the chronically under-sampled South Pacific Ocean

The planned work is organized in two main work packages (WP) on the basis of the scale of the studied processes: “WP1 - Submesoscale” and “WP2 - Regional scale”.

WP1 - Submesoscale studies

Regarding the submesoscale processes, it is known that they directly influence the characteristics of the marine food web and the efficiency of the biological pump and the carbon export. Indeed, the ecological response to submesoscale dynamics can rapidly propagate to the higher trophic levels (Tew Kai et al., 2009; Cotté et al., 2011). Sea surface temperature (SST) and ocean color have long term provided surface observations at the O(1 – 10) km scale, indicating the ubiquitous presence of submesoscale fronts and filaments in the oceans. Information on submesoscale dynamics can be retrieved only indirectly through the analysis of the mesoscale-induced stirring, most commonly by computing Finite Size/Time Lyapunov Exponents (FSLE/FTLE, d'Ovidio et al., 2004). Such information has been often combined with products derived from ocean color observations to investigate the impact of submesoscale dynamics on biogeochemical (e.g. chlorophyll standing stocks, Rossi et al., 2008) and ecological processes (e.g. spatial distribution of the ecological communities, d'Ovidio et al., 2010).

Although the in situ observation at the submesoscale represents a major challenge, many recent studies have shown that observations made by ship-towed profilers, such as the Moving Vessel Profiler (MVP), are extremely effective for collecting repeated synoptic sections of submesoscale structures, enabling an exhaustive investigation of the rapidly-evolving frontal dynamics (D'Asaro et al., 2011; Nagai et al., 2012; Hosegood et al., 2013).

WP2 - Regional scale studies

The satellite remote sensing allowed to obtain a synoptic view in space and time of the physical and biological environment along and during the OUTPACE cruise. Most of the satellite observations are available over time periods longer than 10 years. When possible, the time evolution of these data set will be investigated over the last 10 years. This will allow the characterization of the seasonal and interannual (i.e., ENSO) cycles of physical and biological conditions along the OUTPACE transect, which will help interpreting the measurements and observations performed during the cruise in a broader spatio-temporal context. These satellite observations will also help characterizing the oceanic environment along the east-west gradient investigated by the field campaign.

3.2. ETAT D'AVANCEMENT DU PROJET¹¹

The first step has been to update, develop and organize the software tools for the adaptive strategy in a unique package, provided of a first draft of an User Guide. This work has been done in the framework of a summer internship (June-July 2014, student: L.Rousselet, Aix-Marseille Université). The package has been named SPASSO (Software Package for Adaptive Satellite-based Sampling for Ocean campaigns) and it is freely down-loadable from the web site of the OUTPACE cruise <https://outpace.mio.univ-amu.fr>.

Then, in fall 2014 SPASSO has implemented on two mirroring servers hosted by the SIP (Service Informatique de l'OSU Pythéas) in Marseille and Toulon. First tests have been successful and the software has been activated in operational mode at the beginning of December 2014.

The OUTPACE cruise has been conducted from 18 February to 3 April 2015. The R/V Atalante performed a transect along a W-E gradient from the North of New Caledonia to the western part of the South Pacific gyre (French Polynesia). The oceanographic cruise has consisted in 15¹ short duration stations (SD stations) and 3 long duration stations (LD stations) distributed as shown in Fig.1.

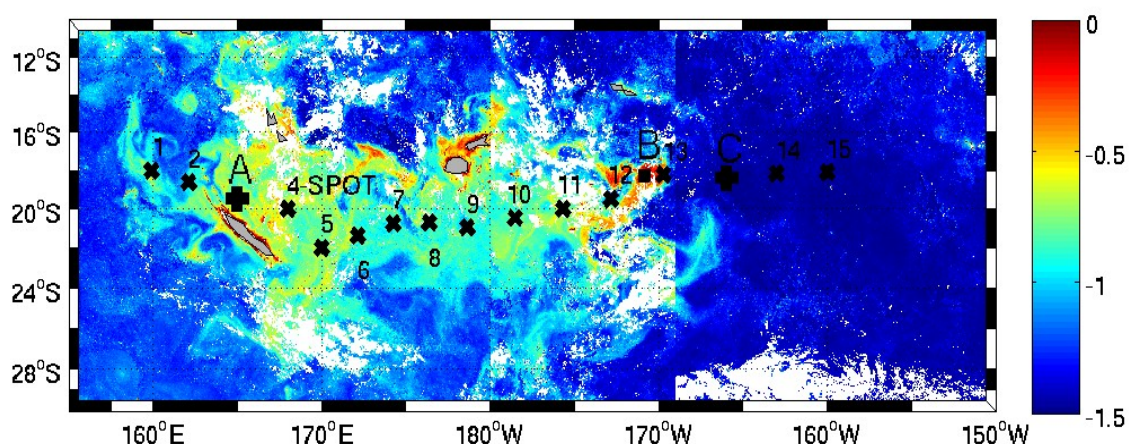


Fig.1 Transect of the OUTPACE cruise superimposed on surface chlorophyll concentrations (data provided by CLS). The cruise performed a series of short duration stations and three long duration stations (A,B,C). In order to put in evidence the sampled mesoscale structures, the chlorophyll map is obtained merging the three maps of days of beginning of the three LD stations.

¹¹The number of SD stations has been lightly reduced with respect planned 17 stations due to the delayed start of the cruise and a stop at Niue in order to hospitalize a crew member.

Following the planned adaptive strategy, the transect initially designed approximatively along the 19°S has been adapted all along the route thanks to the information coming from satellite images, as follows.

The regions along the vessel route has been first characterized at large scale through the analysis of satellite (Altimetry, SST, Ocean color) and operational model data. These will be automatically retrieved and processed to derive Eulerian and Lagrangian diagnostics of ocean circulation and biogeochemistry: Okubo-Weiss parameter maps, Lagrangian Coherent Structures, Chlorophyll maps.

The satellite data has been treated in near real time on land and the treated data have been transmitted on board together with a daily bulletin containing the analysis of remote sensing information and the suggestions for the LD stations positioning. An example of daily bulletin is attached to the present document, while the complete series of the 42 bulletins is available on the OUTPACE website (section “Adaptive Strategy”) at https://outpace.mio.univ-amu.fr/OUT_Figures/Bulletins/

Note that the CLS products on SST and CHL have provided very useful information for the positioning of the LD stations.

The LD-A station has been performed in an anticyclonic recirculation characterized by a relative high CHL concentration.

The severe meteorological conditions due to the development of the cyclone Pam (a Category 5 hurricane) that hit the Vanuatu Islands, obliged to perform the second Lagrangian station (LD-B) at a more eastern location than the one initially planned. The satellite images allowed to target a filament of high CHL concentration. This kind of blooming filament has been already observed in this region at this season and it can have strong influence on the regional biogeochemistry. Several working hypotheses are formulated to explain the presence of such a filament: vertical mixing or terrestrial fertilization or volcanic fertilization associated with the eruption of the volcano Hunga Tonga which started in December 2014 in the Tonga archipelago. The MVP strategy has been adapted in order to perform a section west to east across the structure (Fig.2, very preliminary data).

Finally, as planned the LD-C station has been performed in a cyclonic eddy in the most oligotrophic part of the OUTPACE transect (South Pacific Gyre) in Cook Islands territorial waters.

A total of 13 SVP drifters has been deployed in order to study the surface dispersion at the Long Duration stations. Ten drifters have been provided by AOML-NOAA (Atlantic Oceanographic and Meteorological Laboratory of National Oceanic and Atmospheric Administration, USA; scientific responsible and contact: R.Lumpkin), while three drifters have been bought on LEFE/CYBER fundings. The drifters have been launched as follows: 3 at the LD-A, 6 at the LD-B and 4 at the LD-C (Fig.3).

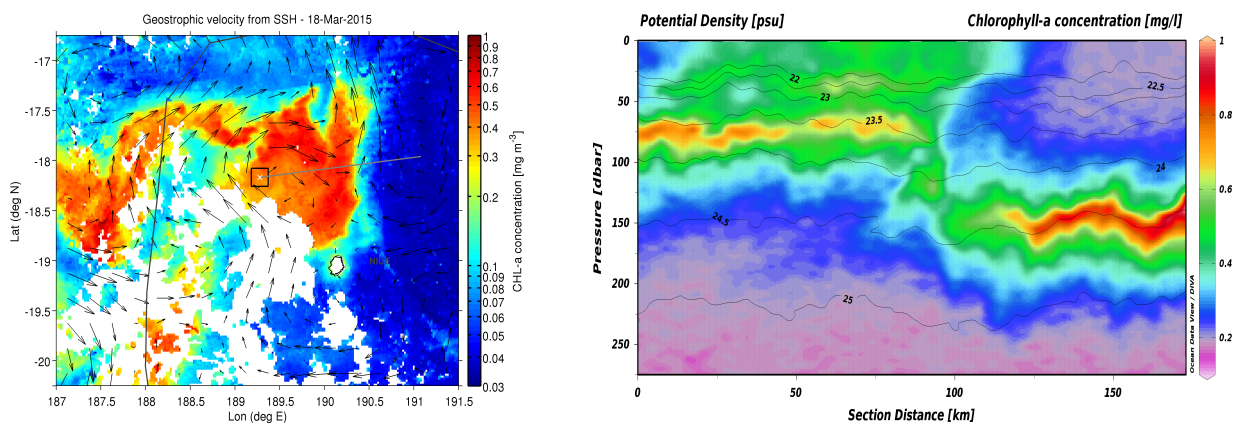


Fig.2 LEFT: Surface chlorophyll concentrations (Data provided by CLS) at the end of the LD-B station. The square represent the last position of the drifting mooring and the gray line the planned MVP transect. RIGHT: section of potential density and chlorophyll-a concentration (values not yet calibrated) along the MVP transect.

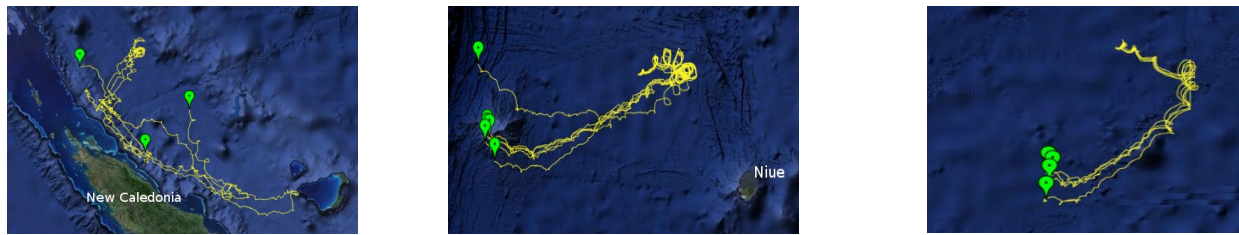


Fig.3 Actual trajectories of SVP drifters launched at LD-A (Left), LD-B (center) and LD-C (right) stations. From the operational website <http://toscagis.univ-tln.fr/> maintained by the SIP (Service Informatique de l'OSU Pythéas).

Moreover, 3 PROVBIO profilers have been deployed, as planned, at the end of each LD stations in order to obtain information linking the submesoscale studies performed during the Lagrangian stations (WP1) and the regional scale observed by remote sensing (WP2).

Finally, 10 ARVOR profiling drifters have been also launched in the framework of the OUTPACE participation at the Argo program (PI: C.Maes, LPO, Brest).

In preliminary conclusion, one can consider that the adaptive strategy has been successfully conducted thanks to the near-realtime satellite information.

The planned M2 student internship started on the 12 January 2015 (student: L.Rousselet, Master d'Océanographie, Université d'Aix-Marseille; supervisors: A.Doglioli and C.Maes). The internship work has been organized in two parts. On one side, the student has helped in implementing the SPASSO software for the adaptive strategy and provided assistance in the analysis of remote sensing data for the daily bulletins during the cruise. On the other side, the student is working on the mesoscale circulation in the Coral Sea and its implications on the biogeochemistry of the region. This study is based on the analysis of the data of a previous cruise (BIFURCATION, PI: C.Maes) and their interpretation supported by the remote sensing information. The preliminary results are very promising, the in situ observations of currents and hydrology have been replaced in their regional context with the help of AVISO altimetric currents and the combined use of data from the SMOS and MODIS missions. We intend to present these results during the next Open Science Conference on Salinity and Freshwater Changes in the Ocean that will be held in October 2015 at Hamburg (via a student poster).

This work will provide a precious framework for the future interpretation of the data collected during the OUTPACE cruise.

3.3. CALENDRIER DU PROJET¹²

Here below the calendar from the last year's proposal is reported. It is generally confirmed, some information about its realization have been added in *italic*.

June 2014: Pre-cruise meeting with all participants (Marseille, France)

Done. The meeting has been organized in Luminy campus the 2 and 3 July 2014 (see details on the OUTPACE project website <https://outpace.mio.univ-amu.fr/spip.php?article111>).

September 2014: Pre-cruise meeting with the organizing committee (Marseille, France)

Done

October 2014-February 2015: Cruise preparation, shipping of equipment to R/V Atalante and Noumea.

Done

January-May 2015: M2 student internship on analysis and treatment of remote sensing data, help in implementation of the software for the adaptive strategy, onshore assistance in identification of sites for LD stations, analysis of regional circulation and biogeochemistry during the cruise.

The internship started the 12 January 2015 (see details above).

February-March 2015: Cruise in the SW Pacific

Done (18 February to 3 April, see details above)

December 2015: Post-cruise meeting with all participants (Marseille, France)

February/March 2016: Workshop focused on physics (~10 people)

May-June 2016: Workshop focused on biogeochemistry (~10 people)

October/November 2016: Workshop focused on remote sensing (~10 people)

2016: Request for a special session at the Ocean Sciences Meeting 2016, New Orleans, Louisiana

2016-2017: Publication of scientific results (Special issue, Journal to be determined)

The post-cruise meeting with all participants is now schedule between April and July 2016 after the thematic workshop focused on physics and remote sensing (~20 people) that is confirmed for February or March 2016.

The special session at Ocean Sciences Meeting or ASLO meeting is scheduled now in early 2017.

The funding from the CNES is requested for the following activities:

in 2015 : i) the purchase of the 9 Lagrangian drifters necessary for the adaptive strategy (3 buoys release at each of the three LD stations)

The CNES funding has not been provided in time to buy the drifters before the cruise. Nevertheless, as detailed above, the planned work has been realized thanks to the fact that 10 Lagrangian drifters have been provided by NOAA and 3 others have been bought with the LEFE-CYBER funding. The CNES funding is then used to cover part of the costs of the travel back in France of some of the instruments used during the cruise and to buy a personal computer for the M2 student, who will benefit of more computational power in the FSLE analysis of altimetry data.

ii) travels and accommodations for the participation to the post-cruise meeting of several experts (see list below)

Confirmed.

iii) the studentship for a M2 student with a special background in mathematics, statistics and data processing;

The internship started the 12 January 2015 (see details above).

in 2016 :

i) the organization of the Remote Sensing Workshop in Marseille (travels and accommodations for participants, catering) ;

As detailed above the workshop is confirmed and merged with the physics one to a better exchange between project participants.

in 2017 :

i) conference participations (fees, travels, accommodations) and ii) publication fees for several papers.

Confirmed.

The experts are S. Alvain (LOG, Wimeraux), J. Bouffard (ESRIN, Rome, Italy), H. Claustre (LOV, Villefranche), F. d'Ovidio (LOCEAN, Paris), C. Dupouy (MIO, Nouméa, New Caledonia), E. Martinez (EIO, Papeete, French Polynesia), C. Maes (LPO, Brest), J. Uitz (LOV, Villefranche).

At the last year's list is added F. Nencioli, previously at MIO (Marseille), now at PML, Plymouth, UK.

Finally, we ask CNES to support our request of access to the regional altimetry products developed by CLS. As detailed above, the SST and CHL product by CLS has been extremely useful for the implementation of the OUTPACE cruise sampling strategy. In the framework of this very satisfying collaboration, we expect that also the CLS regional altimetry product will be very useful for the interpretation of the in situ data, in particular for a region of such a complex bathymetry, as the southwestern Pacific.

3.4. PUBLICATIONS¹³

We plan to present the first results obtained in the framework of the M2 internship at the international conference Open Science Conference on Salinity and Freshwater Changes in the Ocean that will be held in October 2015 at Hamburg.

Cited references

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OUTPACE cruise

SPASSO Images Analysis

22/02/2015 21:42 UTC

Author(s): A.Doglioli

Executive Summary

Station A

A first SD station has been performed at the target site #1.

The target site #2 is positioned to (162.125°E , 18.625°S) as suggested from onboard. It will be joined in the next hours.

Regarding the target site #3, the anticyclonic eddy observed SE of the expected station 5 is no more coherent. A local minimum of speed is still present as part of a larger anticyclonic circulation. The CHL concentration is decreasing in the area. The target site #3 is slightly moved N at (161.9°E , 19.0°S) to find depth greather than 1000m.

The target site #4 is moved to (168.9°E , 22.2°S), in order to find a local minimum of speed.

As suggested from onboard, a new target site #5 is added at (167.2°E , 20.2°S).

Station B

No substantial changes are observed with respect to yesterday's bulletin.

The followed eddies appear less coherent. The target site positions has been updated to follow the eddies that move Wward.

Station C

Not analyzed yet.

Notes

This is an update of the bulletin delivered today at 16:37 UTC.

1 LD Station A

1.1 AVISO data and Lagrangian Analysis results

A SD station has been performed at the target site #1 suggested in yesterday's bulletin. High concentration of CHL has been confirmed by in situ measurement. Instead, a substantial difference between AVISO velocities and in situ LADCP data has been observed. In situ surface(250-m depth) current direction was Eward(ENEward), instead of Wward. In the AVISO data for 21/2 (released today) is observed a change in current direction, actually Nward, due to the Wward drifting of the cyclonic eddy associated with a N-S stretching of it.

A similar Wward drifting seems to be in place also for the anticyclonic circulation N of the expected station 4. The target site #2 is positioned to (162.125°E , 18.625°S)¹ as suggested from onboard.

SE of the expected station 5 a local minimum of speed is still present as part of a larger anticyclonic circulation. It is yet considered as target site #3. This latter is slightly moved N at (164.9°E , 19.0°S) to find greater depths.

The target site #4 is moved to (168.9°E , 22.2°S), in order to find a local minimum of speed. In the next bulletin the bathymetry at this position will be accurately checked, due to the presence of several seamounts.

As suggested from onboard new target site #5 (167.2°E , 20.2°S) is added. Here a well defined anticyclonic eddy is present in an area with high CHL concentration. Nevertheless this eddy is relatively near the Vanuatu ZEE limits and during the last 3 days moved Eward. Such a structure will be accurately followed in the next daily images.

1.2 CLS Regional Products

No substantial changes are observed for area of target site #2.
A decrease of CHL concentrations and SST is observed for target site #3.
The highest concentrations are observed in the area of the new target site #5.
No substantial changes are observed for area of target site #4.

No substantial changes are observed for SST. Remote SST is in good agreement with in situ SST (low frequency TSG data).

1.3 MODIS

No CHL data available.
SST data are generally in agreement with the CLS ones.

1.4 IIYCOM

No data available due a techinal problem not yet resolved.

1.5 Cloud coverage

No data available due a techinal problem not yet resolved.

¹In the previous bulletins there was an error in the text: the mentioned position did not correspond to the figure.

1.6 Suggestions for positioning

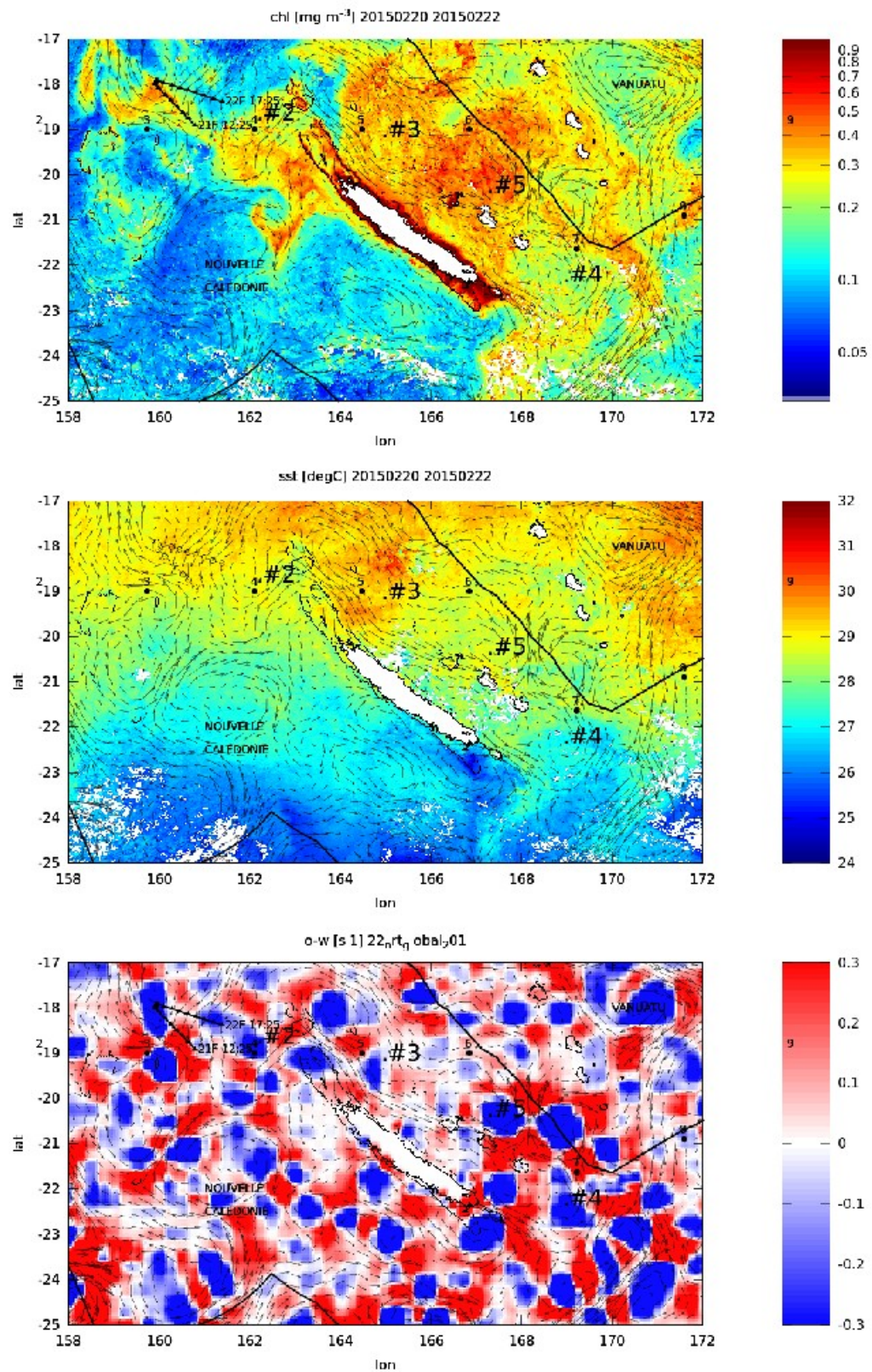
#1 (159.9°E , 18.0°S) SD station performed

#2 (162.1°E , 18.6°S) SCORE: 1/5

#3 (164.9°E , 19.0°S) SCORE: 3/5

#4 (168.9°E , 22.2°S) SCORE: 1/5

#5 (167.2°E , 20.2°S) SCORE: 3/5



2 Station B

2.1 AVISO data and Lagrangian Analysis data

The series of zonally-aligned mesoscale eddies is still observed at about 21°S of latitude and between longitudes 176°E and 184°E. They move Wward and appear less coherent. In particular, the eddy #1 is very few coherent and eddy #2 is separating in 2 parts.

2.2 CLS Regional Products

A general decrease of the CHL concentration and of the SST is observed at latitude 21°S. In particular the CHL concentration decreased in the eddy #3 core and in the eddy #1 ring.

2.3 MODIS

Data not analyzed.

2.4 HYCOM

Data not analyzed.

2.5 Cloud coverage

Data not analyzed.

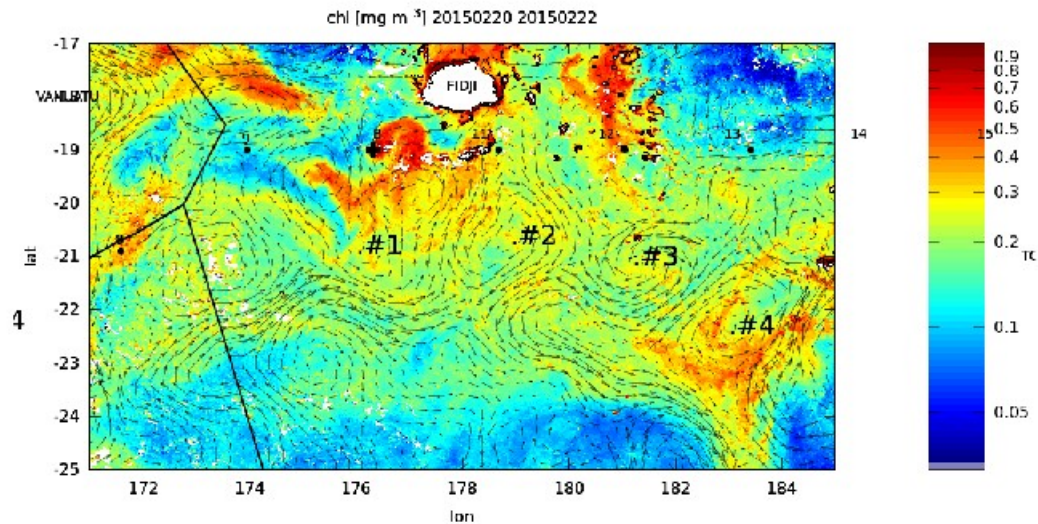
2.6 Suggestions for positioning

#1 (176.°E , 20.8°S) SCORE: 2/5

#2 (178.9°E , 20.6°S) SCORE: 2/5

#3 (181.2°E , 21.°S) SCORE: 5/5

#4 (183.°E , 22.3°S) SCORE: 1/5



Notice d'utilisation de l'imprimé MS-word

- 1 Utiliser le même intitulé dans le fichier MS-word et dans le fichier MS-excel
- 2 Ajouter des lignes si nécessaire
- 3 Les propositions nouvelles sont soumises à l'expertise scientifique d'un groupe de travail thématique du CNES assisté si nécessaire de rapporteurs extérieurs et à l'avis du Comité d'Evaluation de la Recherche et de l'Exploration Spatiale (CERES) pour le domaine Etude et Exploration de l'Univers, ou au comité Terre Océans Surfaces Continentales Atmosphère (TOSCA) pour le domaine Terre, Environnement, Climat. Elles pourront être soumises à une expertise technique et financière du CNES sur la **faisabilité de l'instrumentation** proposée, la **prévision des essais**, le nombre des **modèles** et le **traitement des données**. La **maturité technique** du projet, la **crédibilité du calendrier** de développement et du **coût** seront appréciées, de même que le **contexte coopératif** le cas échéant et le **schéma d'organisation**. La place du projet dans le **plan de charge du laboratoire** proposant et le **volume des moyens propres**, notamment humains, seront également pris en compte.
- 4 En **une page maximum**, indiquer le contexte scientifique au plan national et international. Détailler les objectifs à atteindre sur l'ensemble du projet et les résultats attendus.
- 5 Décrire la situation actuelle du thème de recherche et le projet, notamment le **cadre de réalisation**. Préciser le **statut de l'expérience**, notamment si elle est présentée dans un cadre de coopération internationale : expérience déjà sélectionnée, en cours d'examen ou encore à proposer.
- 6 Décrire la **méthodologie envisagée et les travaux** à réaliser. Décrire le cas échéant le dispositif expérimental et préciser s'il s'agit d'une campagne ballon ou aéroportée.
- 7 Décrire en une page maximum le calendrier de réalisation en donnant les **étapes-clés** du déroulement du projet. Ce calendrier doit être compatible avec l'échéancier financier.
- 8 Les indicateurs que doit préparer le CNES pour ses tutelles ne prenant en compte que les publications mentionnant le nom de la ou des missions spatiales ou instruments, dans le titre ou le résumé, toute publication devra obligatoirement **mentionner dans le titre ou dans le résumé le nom** de la ou des missions ou instruments spatiaux dont des données ont été utilisées.
- 9 Les actions engagées entrent dans le cadre de projets ayant déjà fait l'objet d'une décision positive de soutien par le CNES. **Tout projet engagé doit faire l'objet d'une demande de financement chaque année**. Si les objectifs du projet et/ou son contenu ont été modifiés par rapport à la proposition acceptée, ou si les résultats intermédiaires diffèrent sensiblement des objectifs initiaux, il est demandé d'envoyer une **proposition révisée**. Le CNES se réserve le droit de présenter à nouveau l'expérience concernée au groupe de travail thématique correspondant, au CERES ou au TOSCA et au Comité des Programmes Scientifiques, pour juger de l'opportunité de ces modifications. S'agissant des expériences en cours de développement pour lesquelles une structure de projet a été mise en place au centre de Toulouse, la présente demande de financement doit concerner les **activités d'accompagnement scientifique et les activités de calibration, validation des données**, le financement des activités de développement étant couvertes en principe par le projet.
- 10 **A renseigner avec attention** pour la bonne compréhension des comités d'évaluation, en particulier sur les avancées obtenues par rapport à l'an dernier, et en précisant si les objectifs du projet et/ou son contenu ont été modifiés par rapport à la proposition acceptée par le CNES ou si les résultats intermédiaires diffèrent sensiblement des objectifs initiaux.
- 11 Indiquer ici l'état d'avancement du projet au moment de la demande. Le CNES doit être en mesure de **justifier auprès de ses Tutelles** le financement des propositions qu'il a engagées. Un **bilan des activités de l'année doit être fourni à chaque fin d'année**. Par ailleurs, le paragraphe « état d'avancement du projet » du formulaire MS-word fait office de rapport intermédiaire pour les financements versés à mi-année. Ce bilan qualitatif a pour objet d'exposer l'état d'avancement du projet au moment de la demande, les étapes franchies, les difficultés rencontrées (par exemple, les évolutions éventuelles du contexte scientifique et/ou du cadre de réalisation). Le cas échéant, il détaille comment les recommandations du TOSCA ou du CERES ont été prises en compte. Pour les propositions comportant la réalisation d'un dispositif expérimental : exposer son état de réalisation.
- 12 Rappeler le calendrier d'origine. Indiquer ses évolutions éventuelles et leurs causes. Indiquer les prochaines échéances. Ce calendrier doit être compatible avec l'échéancier financier.
- 13 Pour les projets engagés, donner la liste des publications parues dans des revues à comité de lecture des **deux dernières années** dans le cadre des travaux effectués avec le support du CNES. Toute publication parue dans le cadre de la présente proposition devra obligatoirement mentionner dans le titre ou dans le résumé le nom du ou des missions ou instruments spatiaux dont des données ont été utilisées