Convocatoria de ayudas de Proyectos de Investigación Fundamental no orientada

TECHNICAL ANNEX FOR TYPE A or B PROJECTS

1. SUMMARY OF THE PROPOSAL (the summary must be also filled in Spanish)

PROJECT TITLE: Currents, waves and wind: **I**mproving **R**isk **A**ssessment through **A**ssimilation in **N**umerical models of the **C**oastal **E**nvironment (**COVARIANCE**)

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SUMMARY
The current state-of-the-art in oceanographic modelling provides reasonably accurate forecasts in open sea conditions, but it is not yet equally satisfactory for semi-enclosed domains such as the North Western Mediterranean shelf. This coastal environment is a highly non-linear, very heterogeneous and anisotropic interface, which suggests that these shortcomings in accuracy will not be solved by just running higher resolution models: the progressive refinements in the space-time discretization without simultaneously improving the resolution of driving terms, boundary conditions and sub-grid parameterizations are not enough to improve our predictive capabilities. COVARIANCE aims at achieving this new level of accuracy by assimilating all sorts of data sources into the running (even in operational mode for some target period) wind-wave-circulation models. Due attention will also be paid to the coupling and nesting strategies, in such a way that they result in a robust and efficient operational sequence. The project will, thus, cover: i)the consistent assessment of scales and transfer functions between the considered state variables and measurements; ii)a stable estimation of error covariance structures accounting for past information so that we do not rely only on ensemble simulations; iii) a comprehensive exploration of new ways to partition wave spectra (splitting components of various origins such as sea and swell); iv)the implementation of high-resolution modelling sequences, with the required new coupling terms such that multivariate or inhomogeneous assimilation of wind, wave and current data becomes possible and v)an assessment of the forecasting limits for the whole system, with the aim of optimizing also the sampling and assimilation strategy of the instrumentation network (XIOM network) for operational purposes.

TITULO DEL PROYECTO: **C**orrientes, **O**leaje y **V**iento: mejora del **A**nálisis de **RI**esgos mediante **A**similación en esquemas **N**uméricos de la **C**osta y su **E**ntorno (**COVARIANCE**)

RESUMEN
El estado del arte del modelado oceanográfico ofrece predicciones razonablemente acuradas para condiciones de mar abierto. Sin embargo, estos resultados son hoy en día insatisfactorios para entornos semi-cerrados como la plataforma del Mediterráneo noroccidental: el dominio costero presenta las características de no-linealidad, heterogeneidad y anisotropía típicas de las interfases. Ello sugiere que esta mejora en exactitud no se va a conseguir sólamente con un aumento de la resolución espacio-temporal de los modelos: este refinamiento en la discretización espacio-temporal debe ir acompañada de una mejora en la resolución de los distintos términos forzantes, condiciones de contorno y parameterizaciones de los fenómenos de escala sub-malla. COVARIANCE propone conseguir este nuevo grado de exactitud asimilando todo tipo de datos puntuales a los modelos de predicción de viento, corrientes y oleaje (incluso en entorno operacional). Se considerará también el papel que puedan tener el acoplado de modelos y una estrategia adecuada de anidamiento, de manera que ofrezcan una secuencia robusta y eficiente operacionalmente. Por tanto el proyecto cubre: i)un valoración consistente de las escalas y funciones de transferencia de/entre las variables de estado y las mediciones consideradas; ii)métodos estables de estimación de las estructuras de covarianza de los errores de los modelos y los instrumentos, que tenga en cuenta la información del pasado (predicciones pasadas almacenadas) y no sólo ensembles de simulaciones; iii)exploración exhaustiva de métodos de particionado del espectro de oleaje (identificación de componentes del oleaje, como podrían ser *windsea* y *swell*); iv)implementación de secuencias de modelos de alta resolución, que incluyan los términos de acoplamiento y reparametrizaciones necesarios para poder atacar la asimilación multivariable y la asimilación inhomogénea de oleaje, corrientes y viento; y v)evaluación de los límites predictivos de los modelos obtenidos, con el objetivo de optimizar las estrategias de muestreo de los instrumentos (red XIOM) y su asimilación en modo operacional.

2. INTRODUCTION

2.1. Aims:

The main goal of this project is to further improve the performance at local (e.g. harbour) scales of our operational forecasting numerical models for coastal systems, *by optimizing the way all sorts of local instrumentation data are integrated into the forecasts*. This general goal can be split in two sub-goals. First, we want to improve the wave spectrum estimates for the shelf region in the operational daily wave forecasts, specially under stormy conditions, by better assimilating buoy data. Second, we want to complement the currents and pollutant transport models used in nowcasting during emergency situations with very fast assimilation of currentmeter and sea level data. These improvements, critical in areas of sharp variability, like the Northwestern Mediterranean, will serve to achieve a more robust hazard and risk assessment for harbour and navigation activities, including the structural safety.

2.2. Background:

An efficient management of resources (e.g., wind energy, fisheries), natural hazard (storms) and their assets impacts (breakwaters, ships, promenades), as well as environmental pollution on the coastal environment requires a good understanding of the natural system. This implies obtaining robust long-, mid- and short-term operational schemes for weather and climate evolution, wave or currents, together with the associated sediment, nutrients or pollutant transport; etc.. These are phenomena whose expected behaviour should be forecasted (and nowcasted), in order to advance our response to critical situations or to adapt our exploitation plans.

Although the current knowledge regarding these phenomena and their interactions is more exhaustive than one decade ago and the predictions provided by current numerical models are commonly adequate for open sea conditions, these systems exhibit at the coastal fringe the natural complexity typical of interface systems (in this case, the sea-land-atmosphere), both in time and space scales and gradients, and in the wide range of phenomena involved. Moreover, some of these numerical models have grown so complex that their performance critically depends on the availability of detailed information on our driving terms (sinks/sources, boundary and initial conditions), rather than on the numeric resolution (grid spacing, time step, etc.), a situation strongly recalling the “butterfly effect”. These issues may explain why such prediction systems, though most often delivering useful results, continue performing locally below the accuracy required by present coastal societies, especially when prediction of exceptional or extreme situations is considered. In this line, [Tri+09] even suggests that current models are not going to deliver better results by adding more terms or by allocating them more computer power for increasingly higher resolutions. It is in fact advocated that improvement must come to the level of detail of the driving term fields, and the way data and models are merged. In particular, in the Mediterranean region, affected by strong relief and climate gradients, this calls for a better resolution of such fields, e.g. wind fields for a wave model, or the surface temperature for currents and transport codes.

This is supported by the results of a recently finished research project, RIMA, dealing with the performance of WAM and SWAN, the current state-of-the-art wave generation models [e.g., MP00, Ris97], in the Mediterranean region. This project results suggest that the wind-to-wave energy transfer terms are not adequately reproducing the reality whenever the wind gradients become too large, which brings wave energy underestimations even when the wind field energy was overestimated [AB+09]. All these considerations point towards the importance of devoting attention to measurement-prediction merging schemes for improving forecasts. Data assimilation appears, thus, as the natural next step in this way.

Sequential data assimilation methods can be understood as an application of Bayesian statistics. Here, one first codifies all information available a priori (before looking at the measurements) in a joint probability distribution of the whole *state vector*, i.e. the vector of forecast variables of interest at all grid nodes. Next, one must specify how does the state of a measurement point influence the observations obtained there: this is typically done through a *transfer function*, linking the predicted state variable at the grid point with the expected average, plus an uncertainty around that mean value (e.g. a normal distribution with variance given by the instrumental error). Finally, Bayes theorem offers a way to invert the relationship and obtain the posterior distribution of the whole state vector conditioned to the observed parameters [WB07], from which one typically extracts the mean value as best assimilated forecast. This procedure amounts to computing the residuals between the observed data and the equivalent values predicted by the model, and optimally extrapolating or interpolating them to the grid points of interest [WB07]. This is what is usually called a Kalman Filter (KF). Ensemble Kalman Filter (EnKF, Eve03) techniques work by running several times the numerical forecasting algorithms with an ensemble of perturbed initial conditions, and derive the prior distribution as a normal distribution with mean and covariance estimated by the classical empirical average and covariance of the forecast output. EnKF has shown its usefulness in atmospheric sciences [e.g. Eve03, HM98, TX05], and in complementing transport simulations of pollutants, currents, etc. [e.g. OA+02, RH+05]. However, wave models are so complex that running many ensembles becomes computationally prohibitive in an operational framework, and analysts tend to replace the non-parametric, time-dependent covariance the EnKF delivers by a parametric model, chosen a priori and whose parameters are somehow fitted to the available data and observations [e.g., PM06].

Moreover, most of the current efforts in data assimilation are devoted to merging satellite or airborne image data into forecasts, because remote sensed images provide information about areas, and have thus a geographically larger impact on the results, e.g. [Jor05]. On the contrary, local instrumentation data (buoys, anemometer, currentmeter, etc.) are typically considered to carry information only relevant for a small area around them. However, image data assimilation techniques have been shown to work unsatisfactorily on the coastal area, since this border between land and sea is an interface where the typical analysis assumptions fail (isotropy, homogeneity, stationarity, etc.). These coastal areas are typically well-covered by local instrumentation, which makes these two sources of information fairly complementary to each other. However, the techniques used in both cases must be substantially different, as the KF computational load mostly depends on the number of available data points. While this is a problem in remote sensed image assimilation (where one has hundreds, maybe thousands of pixels as data points), it is irrelevant with local instrumentation, where one never exceeds a "few" (of order 10) locations.

2.3. State of the art

Current state-of-the-art sequential assimilation techniques based on local instrumentation data is dominated by EnKF and some of its simplified derived techniques.

Regarding wave and wind systems, the most common approach is to assimilate wave data from buoys into forecasts of the wave field, and secondarily modify the wind field in order to keep them physically compatible, as e.g. suggested in [VMH97]. In the most typical case, algorithms linearly increase or reduce the significant wave height (Hs), or the amount of energy of the wave spectrum, based on the filtered differences between data and predictions. Note that both methods are not compatible: one either optimally assimilates Hs or the spectral energy, being the relationship between them a multiplicative one. However, [TO+09] has shown that both quantities get compatible when assimilation applies a multiplicative correction. Other schemes include also assimilation of information from the main period and the main direction, if these are available from buoys (as delivered, e.g., by pitch-and-roll buoy data), either directly or via a Cartesian representation of these two quantities taken as polar coordinates of the main spectral class [VMH97]. Some buoys deliver information about the whole directional wave spectrum, in the form of energy allocated to each frequency-direction bin within a discrete 2D polar grid. Up to now, all attempts to incorporate this information into the WAM and SWAN models has been done using the concept of spectral partitioning. Partitioning is also used for the case of integral or averaged descriptors of the spectrum, which introduces further uncertainty depending on the wave field features, particularly for bimodal sea-states, as found commonly in the NW Mediterranean [BS06, BJ+09].

Wave spectra are known to be a mixture of several components, generated by local wind conditions or by distant swell. The idea behind spectral partitioning within assimilation schemes is to: (1) split the spectra of forecasts and data alike into wind or swell classes; (2) relate each component of the forecast spectra with a component of the data; and eventually (3) apply the assimilation algorithms only for associated numerical-observation pairs of bins of the spectrum, adjusting the forecast energy to the observed one. Though conceptually superior to the direct assimilation of the unsplit spectrum, the fact is that these methodologies may become rather heuristic, especially in step (2), and require experienced users. [Ger92] was the first to propose one of these algorithms, while a summary of other approaches can be found in [Por09]. This author also covers the assimilation step.

Regarding current and transport equations, these typically solve the flow and accessory state variables with an implementation of the Navier-Stokes equations with Reynolds simplifications, together with temperature and salinity transport equations, complemented with continuity equation and a state equation relating density, salinity and temperature. This is the case of the ROMS system [e.g., SW05], available in the LIM. There are are hardly any applications of direct assimilation of currentmeter data into current fields, as one expects much more information from surface property images than from local instrumentation. Therefore, most of the effort has been devoted to condition forecasts to images of sea surface height, vorticity, temperature and salinity, e.g. [FR+99, OA+02, Jor05].

This project, though focusing on assimilation, considers also the role that other improvements on the numeric algorithms themselves may play. Coupling of wave and current models has already been obtained for SWAN and ROMS at a restricted scale, e.g. [WPS08], adequate for local harbour management and small shelf dynamics modelling [WS+08]. Regarding wave-wind interactions, the free-surface air-sea coupling is particularly important for inhomogeneous and transient situations typical of limited domains [JD+02]: several parametrizations of this effect have been proposed [e.g. BW08], but not yet reached an operational prediction.

2.4. References

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2.5. Other groups active in the subject

The day to day prediction of wind, current and wave fields along the European Coast is in the hands of the various meteorological services in each country. They cooperate with other research institutions like Universities or research centres for the more scientific aspects such as the couplings, parameterizations, boundary control, nesting and downscaling, etc. In the EU the reference centre for operational predictions is the European Centre for Medium Range Weather Forecast providing mid scale resolutions for the wave fields along European Coasts. They also carry out advanced research as illustrated by the work of Dr. P. Jenssen and co-workers. This is done in cooperation with the National Meteorological Centres, which for the case of Spain is the *Agencia Española de Meteorología* in cooperation with *Puertos del Estado*. Similar work is done by the UK Met-office, the DK Met-office or Meteo-France.

At a more local level there are a number of regional meteorological centres providing operational predictions for winds/waves/circulation as illustrated in Spain by Euskalmet, Meteogalicia and *Servei Meteorologic de Catalunya*. They work in cooperation, respectively with AZTI in the Basque Country, Universidad de Santiago de Compostela in Galicia or the LIM-CIIRC/UPC Group in Catalunya (the group behind this proposal).

Assimilation and local scale predictions, including research on performance, limits and parameterizations, have also been considered in advanced research institutions throughout the European Union. The Proudman Oceanographic Laboratory in the UK, the DHI in Denmark, LEGOS in France or the GKSS in Germany perform such a role in the context of their own national research and for European Union research projects such us ECOOP or MyOcean, both of them active at the time of writing. In Spain there are good examples for research on wind/current/waves operational predictions including partial assimilation within institutions such as the Barcelona Super Computing Centre, IMEDEA–Universitat de les Illes Ballears, Universidad de Cantabria or Universitat Politècnica de Catalunya. A good example of this effort was the ESEOO project which brought together more than 10 spanish institutions with the goal of promoting the operational oceanography.

More in-depth research aspects have also been analyzed recently by a number of groups in the European Union. We can mention Mercator, The Catholic University of Lovaina, The SHOM (*Service Hidrographique et Oceanographique de la Marine*) in France, or ISMAR-CNR in Italy and the LIM-CIIRC/UPC Group in Spain. All of them have developed new terms (e.g. for wave/current coupling), new strategy/downscaling techniques (e.g. for beach/harbour applications) and new approaches to the assimilation of remote images and in-situ data.

The chain of nested simulations has been extended to a number of derived products such as transport (suspended sediments, pollutants, etc.), flooding and navigation hazards and similar. Good examples of this work are provided by DHI, Mercator, *Puertos del Estado* and many other research groups. The corresponding assimilation is, however seldom directly extended to these products since point-wise measurements have been relatively less employed for conditioning (see explanation in the proposal description). The effect of this strategy and the evaluation of assimilation benefits at such scales are not fully known, and will be the focus of this project.

3. OBJETIVES

- **3.1** Describe the reasons to present this proposal and the **initial hypothesis** which support its objectives (maximum **20** lines)

The project focuses on improving present wave and current forecasting ability, by using sequential assimilation using point-wise instrumental data in the coastal region (shelf area). This has up to now received only marginal attention, because of the *quantitatively* low impact expected for such data, in comparison with air- and spaceborne imaging assimilation. However, remote image assimilation results in the land-sea interface are unsatisfactory, due to the sharp gradients in the field variables. This, together with the high requirements on accuracy and robustness of end-users from the coastal areas (e.g. harbours, offshore, single point moorings, navigation) call for an assimilation of local instrumental data.
The starting hypothesis is that this will have a *qualitatively* important impact in understanding and predicting the behaviour of the studied systems, which are also dominated by local gradients. In our opinion, this improvement can only be achieved with data assimilation, because the alternative, increasing the level of detail of the numerical grids, would require an equivalent level of detail for the input data and sub-grid parametrizations, nowadays unavailable. Moreover regarding wave fields, assimilations based on a full spectral description is computationally cumbersome. It becomes even worse when considering wave-current interactions, so that purposely running ensembles for an EnKF is not operationally feasible. Our hypothesis is that the recent past history of simulations contain the same information, and this would allow a more efficient operational implementation of assimilation.

- **3.2.** Indicate the **background and previous results** of your group or the results of other groups that support the initial hypothesis

[Tri+09] showed that no up-to-date numerical routine of weather forecast profit from just an increase in grid resolution, because we cannot feed the models with the actual source term fields (driving forces, initial and boundary conditions) at an equivalent level of detail.

[TO+09] derived meaningful covariances for the significant wave height for assimilation purposes with the history of the last 3 years, avoiding running wave simulations for EnKF covariance estimation. We also showed that a log scaling of the significant wave height yields compatible spectral energy and wave height assimilation, pointing to a strategy of consistent scaling for the assimilated variables.

[AB+09] showed that in the Mediterranean, wave energy is commonly underestimated under storm conditions, even when the wind field is overestimated. This was attributed to the limited storm fetch and duration, together with the strong gradients of this region. This highlights the importance of having accurate local information, both for winds and waves.

(references given in section 2.4)

- **3.3.** Describe briefly the **objectives** of the project.

1. Data scaling and transfer functions (general). Nowadays, most assimilation transfer functions are simply linear functions of the state variables. We have already shown the potential of enriching that to scaled variables (e.g. log transformed). Our goal here is to determine the best scaling and transfer functions for the meteo-oceanographic of data and models we manage, explicitly considering the advantages of a non-linear function, as suggested by the explosive weather events typical of the NW Mediterranean.

2. Bayesian covariance estimation (general). The core of any KF technique is the estimation of the

covariance matrix of the state variable between any pixel, or between the state at any pixel and the instrument measurement. These matrices are large (order of number of grid nodes), and may not be reliably estimated with the small samples (of ensembles or history of forecasts) available. We aim at increasing the robustness of this estimation with a Bayesian approach to the assessment of the covariance itself.

3. Partitioning algorithms and other representations of the spectrum (waves). Existing algorithms of wave spectra partitioning are typically heuristic, requiring certain expertise for an efficient use. We aim here at a better understanding of this partitioning, possibly generating alternatives, either based on algorithms of principal component analysis, unmixing (well-known in geology and environmental sciences), or in a low-dimensional wavelet representation of the spectrum. This will allow for a more objective and user-independent approach, with a more controlled level of error.

4. High-resolution coastal meteorological model (wind). Wind field uncertainties have been regularly blamed for underestimations produced in the wave generation models. This task will address this issue, by generating high-resolution wind files for the domain under study, from numerical simulations of a state-of-the-art mesoscale meteorological model. Assimilation of climatological data will also be considered here.

5. Currentmeter assimilation (currents) We aim here at assessing the impact of local (point-wise) assimilation for current fields when compared with conventional 2DH conditioning schemes (images, conveying almost no direct information on depth). Special attention will be paid to the possible complementarity of both methods, and the role of 3D current assimilation in the full 3D circulation field.

6. Wave-wind and wave-current model interaction terms (general). This task aims at understanding the role of interactions between waves, winds and currents, especially in contrast with the assimilation process. The non-linearity of weather fluxes in shallow areas plus the sharp gradients in time and space found in the Mediterranean coastal region, suggest an investigation to improve local-scale predictions.

7. Inhomogeneous assimilation (general) We aim here at studying algorithms of assimilation of one variable onto a different state variable, possibly compensating for the limited interaction terms included on the numerical models. For instance, we may modify the wind field from significant wave height data. This should allow a two-step assessment of the achieved improvement, first in terms of the driving wind field and then in terms of the resulting waves.

8. Prediction limits of the operational framework (general) Due to the sharp gradients and strong non-linearities of the coastal region, we may expect assimilation to have a short time influence, i.e. if we stop assimilating, forecasts and data diverge very fast from each other. Characterizing this time memory is vital to assess the potential gain of multiple assimilation versus simple assimilation (more than one variable or just one), to optimally plan the sampling scheme of measurement instruments, or to assess the suitability of the developed algorithms for operational predictions.

4. METHODOLOGY AND WORKING PLAN

Detail and justify precisely the methodology and the working plan.

The project pivots around several test case studies, covering the most significant situations in time, and socially important transects in space. For the time dimension, we have chosen three pairs of benchmark storms in the Catalan coast, each pair under one of the dominating wind regimes of these areas (*Mestral*-N-NW, *Garbi*-SW, and *Llevant*-E), one of high intensity, one of medium-low intensity. For the spatial factor, two case study locations are chosen: the areas around the harbours of Barcelona and Tarragona. These case studies are consistently used throughout the whole project, according to the following scheme of goals, tasks and deliverables.

Note: all references are collected in section 2.4. The chronogram is included in an appendix.

G1. <u>Data scaling and transfer functions</u>. Most data assimilation applications devote no attention to a careful scaling of the variables of interest (both data and state). We have already mentioned how results obtained linearly assimilating buoy measurements as significant wave height or as spectral energy differ, but they coincide if we work with a multiplicative assimilation. That is equivalent to the simpler linear assimilation of log-transformed wave heights. In a similar fashion, it is not the same to assimilate information about mean period-direction information on such polar coordinates than using its Cartesian representation as mean period in direction west and north. Transfer functions deserve also some attention: recall that these give the expected observations conditional to the forecast state. For instance, the expected significant wave height measured in a buoy may be taken as the forecast wave height for the nearest grid node. Thus, before any further theoretical development, it is necessary to establish these two concepts for the range of data and states used. This is specified in the following tasks:

<u>Task 1.1</u>. scaling the output parameters of our numerical algorithms: significant wave height, mean period and mean direction, or energy at each spectral class for the wave field, and speed and direction for wind and current fields. The proposed way to do this is to apply several transformations to the data set, and *study the structure of principal components* (PCA), also known as empirical orthogonal functions (EOF), *of each transformed data set* (deliverable D1.1a). The one with a clearest interpretation will indicate the best scaling transformation for the studied variables. Finally we will build a reference *table of scaling transformations for all state parameters* (deliverable D1.1b), based on existing literature references and these EOF evaluations.

<u>Task 1.2</u>. scaling buoy data: in the same way, each buoy output must be characterized, in terms of its precision (e.g., some provide data in integer cm, other in dm), scaling and relation to the actual wave height. Some of the buoys available are scalar, delivering the energy distribution on several wave frequencies, while other are directional, providing full information about the distribution of energy in direction and frequency. Deliverable D1.2 is an *assessment of scaling and transfer functions* for each buoy we have available.

<u>Task 1.3</u>. scaling current data: these are measurements of direction and speed at 1m and 15m depth, both the average and the maximum of 10 minute periods. This is complemented with water temperature measurements at these two depths. Regarding just currents, we may work with data in those polar coordinates, in log-polar coordinates, or in Cartesian ones. Deliverable D1.3 will be an *assessment of which is the best scaling*, and the corresponding transfer functions.

<u>Task 1.4</u>. scaling wind data: wind is characterized in the same way as currents (with direction and speed, both for the maximum and the average each 10 minute period) and at the same locations. The same scaling transformations are a priori proposed. Deliverable D1.4 is an *assessment of scaling and transfer functions* for each available instrument.

G2. Bayesian covariance estimation (general). As mentioned, KF techniques require the estimation of a large covariance matrix. To obtain a statistically reliable estimate we would need a consequently large sample of ensembles, which is typically not operationally available [FB07]. We have already shown that ensembles can be satisfactorily replaced by the whole history of stored forecasts, but this is only useful to obtain a time-independent covariance. Two intertwined improvements are proposed in this line:

- First, the estimation of the state-state covariance can be robustified using a bayesian perspective: choose a prior distribution for the covariance, update that prior by the available "data" (in this case, ensembles or history of forecasts), extract the mean of the posterior distribution as best estimate. A canonical choice of prior distribution would be the Wishart model, which depends in turn on a hyperparameter covariance matrix. In this case, the posterior mean is the harmonic average of the hyperparameter and the classical covariance estimator, which computation requires the inversion of three large matrices. This line is planned as follows:

Task 2.a: study of existing prior distributions, their properties, and interpretation of the structure of the hyperparameter covariance matrix (e.g., how do we encode with it the soft information about the known weather teleconnection patterns). This will finally deliver a *suitable prior distributions catalogue* (D2.a).

Task 2.b: study and adaptation of existing algorithms of inversion for large matrices, adapted to the characteristics of the involved matrices (positive definiteness, block-diagonality, etc.). The final joint deliverable of this and the preceding task should be the full *best algorithm of robust estimation of a single covariance matrix* (D2.b).

- Second, it would be desirable to allow the covariance matrix to evolve with time, adapting to the weather characteristics. The preceding algorithm can be then applied to an ensemble of perturbed forecasts (thus enhancing EnKF), or when this is operationally not feasible, to a subset of the existing forecast history. This last case will be considered in the following task and deliverables:

T2.c: propose algorithms of estimation of an evolving covariance, by only using the subset of the stored forecasts which are somehow better related to the present situation, or by using a weighted estimator of the covariance. For instance, we may select only those forecasts of the day after those 100 days more similar to the present day, in order to obtain a forecast for tomorrow (the *performance of this heuristic algorithm* will be studied in deliverable D2.c1). However, we will also look for a *theoretical grounding of this or a similar algorithm*, probably using a sort of likelihood of each forecast (deliverable D2.c2). Note that all these criteria depend on the scaling of the variables used (deliverable D1.1). Finally, these algorithms will be *applied to the test situations* (deliverable D2.c3), in order to assess their practical performance in comparison with the assimilation obtained with classical covariance estimation or determination methods.

G3. Partitioning algorithms and other representations of the spectrum. As far as we know, objective unmixing techniques, well known in geology and environmental sciences, have yet not been applied to spectral decomposition. *Unmixing* is the name given to the recasting of a composition (a vector of positive components) as a convex linear combination of some endmember sources [Wel97]: most of these techniques inherit its objectivity from the statistical principal component analysis (known in ocean and atmospheric sciences as *empirical orthogonal functions*, though residually applied beyond the characterization of long-range weather interactions). Finally, intermediate steps between assimilating each node of the spectrum (e.g. 12x13=156 nodes) and assimilating the few (2 to 5) components of a partition could be to work with a low-dimensional representation of the spectrum. This may be obtained, e.g. with wavelet analysis, empirical mode decomposition, ARMA modal decomposition, etc.. Wavelet analysis extend the concept of Fourier analysis, in which the data series is decomposed as a combination of a few (approx. 10-25) damped quasi-periodic basis functions. Again, wavelet analysis has a very low penetration in oceanography, but e.g. [WJ+03] estimated the covariance function in data assimilation. Empirical mode decomposition works with the same goal, replacing the Fourier transform by a Hilbert transform [HS+98]. Finally, ARMA modal decomposition [EG87] is based on characterizing the direction spectrum in the complex plane. This goal is divided in the following tasks:

T3.1. exhaustive search of literature references and software for partitioning wave spectra, which will deliver a *ranked database of existing methods*, with characteristics, advantages and disadvantages (D3.1).

T3.2. application of unmixing algorithms and PCA to the spectra partitioning problem, and comparison with the best methods existing up to now. This will yield a *study of the characteristics, advantages and disadvantages of unmixing of spectra* (D3.2), in comparison with the existing methods.

T3.3. use of low-dimensional representations to flexibly model wave spectra, and comparison with the best methods existing up to now and those derived from unmixing algorithms. This will provide a *catalogue of wavelet basis suitable for spectral modeling* (D3.3).

T3.4. comparison of the performance of assimilation using each of the methods studied in the preceding tasks. This will deliver a *performance assessment of the proposed unmixing algorithms and wavelet basis* (D3.4a, D3.4b). These studies should ultimately indicate which one is the *best method of spectral characterization for assimilation purposes* (D3.4c).

G4. High-resolution coastal meteorological model. Wind field uncertainties are typically considered as the source of important wave energy underestimations of WAM and SWAN. In theory, that could be solved by using higher resolution wind fields as input, but these must be more than simply downscaled versions of the large-scale models. In order to be effective, they must address the strong orographic gradients of the Spanish Mediterranean coast, and include as much “real data” as possible. This goal will be achieved in the following steps:

T4.1. Software implementation and model optimization in MN. High-resolution wind files for the domain under study will be provided from numerical simulations of a state-of-the-art mesoscale meteorological model. The meteorological model Weather and Research Forecasting Modelling System (WRF) will be applied at high spatial resolution. WRF implementation will run in the supercomputer Mare Nostrum hold by the Barcelona Supercomputing Centre. High-resolution models demand large computing resources, thus, the model performance within MareNostrum supercomputer will be optimized for this project.

T4.2. Sensibility studies in coastal areas. In order to provide the best coastal meteorology, several numerical experiments will be designed and the geophysical databases will be updated with accurate land-use maps, coastal lines and digital terrain models. Sensitivity runs will be performed to assess the best PBL scheme to implement for coastal meteorology. WRF model includes a set of PBL parameterizations of local or non-local nature, and accounts for turbulent kinetic energy estimation (Deliverable D4.2 *sensibility studies in coastal areas*).

T4.3. Assimilation of available meteorological observations. Assimilation techniques will be assessed to quantify the impact of *mesonet* observations and wind on buoys measurements on surface meteorological results. Boundary layer processes are complex to reproduce and the assimilation of near-surface observations will contribute to improve the model skills. Also, nudging techniques of atmospheric analysis will be applied to improve the synoptic forcing within the mesoscale domain characterized by *Mestral* (N-NW), *Garbí* (SW) and *Llevant* (E) local circulations (Deliverable D4.3 *assimilation of available meteorological observations*). Note that this may require results from deliverables D7.3 and D8.3.

T4.4. High-resolution coastal meteorological modelling. BSC will provide high-resolution model results (spatial resolution of 1 km^2 and temporal resolution of 1 hour) for several meteorological variables (surface wind speed and direction, surface temperature, atmosphere-sea and atmosphere-land heat and moisture fluxes, precipitation, relative humidity, etc). This may be useful for the reparametrization steps of task T4.1c.

T4.5. Model evaluation. The meteorological model results will be quantitatively evaluated against available meteorological observations (radiosounding, surface meteorological observations, buoy observations). Statistical methods, both classical and new, such as categorical metrics and scale assessment (deliverables D1.1b and D1.3), will be used to identify the systematic biases of the modelling system and improve the final model results by applying post-processing algorithms (Deliverable D4.5 *meteorological model evaluation*). Wave forecasting quality (as delivered after D6.1c) will also be considered as an indicator of wind forecasting quality, because wave fields have an integrating effect on wind fields.

T4.6. Operational framework implementation. The final task of this goal will be the implementation of the preceding model in an operationally feasible scheme (nesting, grid sizes, instruments, assimilation covariance estimation, etc.) for the coastal area (Deliverable D5.5 *operational scheme*). This may include inhomogeneous assimilation schemes (from Deliverable D7.3). The goal is to serve the (operationally best) possible wind predictions to the wave generation models of goal G6.

G5. Currentmeter assimilation (currents) Remote sense image current assimilation is nowadays mostly merging sea surface information (2D images, for instance sea surface height) into the 3D circulation field, a 2DH conditioning scheme (not a full 3D approach). Our goal here is to introduce depth information coming from local (point-wise) currentmeters, and compare the obtained assimilation with conventional 2DH schemes. The first step for a consistent circulation assimilation scheme will be already covered by deliverables D1.3 and D1.4. This will be continued with the following set of tasks:

T5.1. reference search of existing methods of assimilation of water speed information on the circulation patterns, and *selection of the best assimilation method* (D5.1), according to the fact that velocity is a rapidly-changing property. Kalman-based methods will be preferred, to give consistency to the project.

T5.2. evaluation of the *spatial covariance structure* (D5.2), using the current model implementation for the study sites (Barcelona and Tarragona harbours) and maybe the methods developed for waves in task D2.c1 and D2.c2.

T5.3. Implementation of the *assimilation routines for the chosen method* (D5.3), in such a way that they may be in the future called from within the ROMS code. In doing so, we allow for posterior developments in which we might merge assimilation and forecast at a very small time step, depending on the memories obtained from deliverable D8.2c.

T5.4. practical check of performance of the algorithms obtained at the two small-scale study sites (Barcelona and Tarragona harbours), to obtain an *evaluation of currents assimilation quality improvement* (D5.4). This and the preceding tasks will be covered early enough to allow for a different choice of assimilation method, if results are not satisfactory enough.

G6. Wave-wind and wave-current model interaction terms (general). It has been already mentioned that wave generation models do not fully capture the energy transfer from wind to wave fields. It has also been observed that wave-current interactions in the Atlantic may be significant, whereas they have been so far considered unimportant in the Mediterranean [JB+07]. This task aims at improving the coupling estimates and eventually testing new interaction terms, while comparing the improvement due to these terms with that of assimilation. This is divided in two subtasks, with its own structure of milestones and deliverables:

G6.1. Improved wind-wave transfer interaction terms in wave models. The leading idea here is to check the impact on forecasting quality of some new wave growth and dissipation functions. In the preceding project RIMA, some terms proposed in the literature were evaluated, but none is yet implemented operationally. Moreover, in the present project the improvement due to these terms will be evaluated with regard to the gain provided by assimilation. This is split in the following tasks:

T6.1a. exhaustive search of existing proposals of wave growth and dissipation functions, expressing them as a function of dimensionless fetch, duration and wave age. This will deliver a *reference list of existing wave evolution proposals* (D6.1a). To these we may add any suggestion coming from the scaling analysis of goal 1 (deliverable D1.1b).

T4.1b. check of the most promising new functions, with and without coupling with currents. This will yield a *study of the characteristics, advantages and disadvantages of wave growth and dissipation terms* (D4.1b), in comparison with the functions implemented nowadays. Note that current interaction requires deliverables from goal 6.2.

T6.1c. investigate the suitability of parametrizing the wave growth/dissipation terms as functions of the turbulence level in the air-water atmosphere. Proxies of this turbulence to be considered are the differences on water/air temperatures, or wind/wave speeds and directions. This should provide a *study of the role of air-sea interface turbulence in wave growth systems* (D6.1c). Note that temperature differences will only be available from task T4.4 or deliverable D6.2a.

G6.2. Coupling wave and current models. The LIM-CIIRC runs operationally the WAM and SWAN wave generation models (in fact the operative Western Mediterranean wave state forecast of the Catalan Meteo Service -SMC- was a joint venture between the LIM-CIIRC and SMC), and ROMS code to model currents in the areas of Tarragona and Barcelona. The aim here is to build a common framework for these two models, suitable for including assimilation of various data sources. This goal contains the following framework task:

T6.2a. advancing in the implementation of a suitable joint ROMS-WAM system (grid, nesting, parameters, structure of internal calls, etc.) for current and wave prediction. In this task we will address the possible redefinition of space-time grids for the western Mediterranean using WAM or SWAN code for waves and ROMS code for circulation, aiming at an optimal nesting-coupling between them, and a univocal identification with the localization of assimilating measurement instruments. Project RIMA explored the interactions of WAM wave simulations with *Symphonie* circulation fields: COVARIANCE migrates to ROMS because nowadays there is a larger active group behind it, and because a number of Spanish groups (including the LIM-CIIRC, as well as e.g. *AZTI* or *Puertos del Estado*) have agreed to use ROMS as a standard. The single deliverable of this task is the corresponding *software implementation* (D6.2a). It may also provide the sea surface temperature maps, needed in task T6.1c. As an example of the possible role of this variable, sea surface temperature is supposed to explain part of the wave model errors, e.g. *Mestral* storms in the NW Mediterranean at the end of the summer season, before the thermocline is eroded by winter conditions.

T6.2b. Coupling direction evaluation. Once the coupled model is working (deliverable D6.2a), it will be used to compare circulation forecasts with and without wave interactions, and vice versa, wave forecasts with and without current interaction, to elucidate whether coupling in this region is significant or not, as suggested by [JB+07].

G7. Inhomogeneous assimilation (general) We aim here at studying algorithms of assimilation of one variable onto a different state variable, e.g. the modification of the wind field from significant wave height data, in the line of [VMH97].

T7.1. exhaustive search of literature references about inhomogeneous assimilation, to build a *catalogue of existing applications of inhomogeneous assimilation* (D7.1).

T7.2. characterization of the perturbations on transfer functions (filters) of each instrument induced by strong events of a different variable, e.g. waves during storms larger than the height of the anemometer reduce the average wind speed. Equivalent effects can be devised for currents under wave storms, or wave measurements under strong currents. This will provide an *assessment of multivariable transfer functions for buoys, anemometers and currentmeters* (D7.2a,b,c).

T7.3. practical implementation of inhomogeneous or multivariable assimilation, to obtain an *evaluation of assimilation quality improvement* (D7.3). Note that this is connected with deliverable D8.3.

G8. Prediction limits of the operational framework (general) An implementation of the assimilation algorithms developed here should be operationally useful for the data acquisition schemes and numerical forecast models available. Because of the non-linear behaviour of the natural systems modelled, we may expect that the perturbations of the forecast fields due to assimilation decay very fast if data are not continuously assimilated. Assessing the memory of our algorithms to assimilation is thus vital, as is to characterize those factors controlling it.

T8.1. extensive measuring campaign along the Catalan Coast, to monitor the set of local instrumentation available (anemometers, buoys, currentmeters) during the whole project. The natural deliverable (D8.1) of this task is a *growing data set* of all available variables, for use in all the assimilation and numerical experiments of this research project.

T8.2. evaluation of memory time for homogeneous schemes. The challenge here is to devise the proper time step at which data must be assimilated so that its “signal” persists. We propose to compare the evolution of forecast runs with and without assimilation under the same regime, both at local scale (one pixel) and regional scale (averaged behaviour of the influence area around the instrument location). This will deliver some *assessments of the assimilation memory of buoys into the WAM* (D8.2a), *winds* (D8.2b) *and currentmeter into ROMS* (D8.2c). The goal is to evaluate whether the data acquisition schemes (i.e. frequency of measurements, whether they are averages or maximum values during intervals, etc.) of our instruments are good enough for these memories. Therefore, these assessments will consider the memory as a random variable, compensating for several sources of uncertainty (like the weather situation, or the instrumental error). This is particularly important for flow variables (water speeds), because they are very unstable in space and time.

T8.3. comparison of the performance of single vs. multiple assimilation. This will deliver a *complementarity performance assessment of the several variables considered* (D8.3), i.e. which variables better complement each other, extending their joint memory range. The proposed methodology is again to compare runs with and without several variables assimilated, and consider how the memory distribution changes. This is connected with deliverable D7.3: while the latter focuses on the effect of assimilating several variables into one single field (e.g., wave and currents into waves), the former deals with the effect of simultaneous assimilation of several variables into their corresponding fields (waves into waves and wind into wind simultaneously). We will incorporate here particular numerical metrics/scales (like those obtained in D1.1b) to bound uncertainty, e.g. as a function of geometry, mesh nesting ratios and the energetic level of the event considered.

T8.4. Global operational framework implementation. The final task of this project is the definition of best practices for the implementation of an operational framework of wave-wind-current forecast, including assimilation of as many data sources as possible (Deliverable D8.4). This includes the specification of optimal nesting schemes and grid sizes for the cascade of models, the selection of instruments to assimilate, the sampling characteristics of these instruments (which magnitudes are measured, how frequently), the choice of the best "moment" to assimilate each data type to a model of the cascade, etc. This may include inhomogeneous and multivariable assimilation schemes (from Deliverables D7.3 and D8.3). The ultimate goal of this task and of the whole project is that the benefits of these results arrive the end-users.

5. BENEFITS DERIVED FROM THE PROJECT, DIFUSION AND EXPLOTATION OF RESULTS

The most important benefit of this project is a better accuracy and precision of future wave and current operational forecasts, which will directly improve their reliability during decision and policy making for several endusers: navigation, harbour and beach management, fisheries and in general any institution with interests around the coastal domain. This will be articulated along two lines. First, our partner (SMC) serving wave and wind forecasts to private stakeholders and policy makers, will have better products to offer. Second, the public agencies in charge of harbour and navigation management (*Puertos del Estado*, the Spanish harbour management agency, and the autonomous administration agencies of the Barcelona and Tarragona harbours) in the Catalan coast will be provided with better current and wave forecasts. Last but not least, this project will enhance our use of the multiproxy measurement network of the LIM-CIIRC, established through past and present projects and contracts with the Administration, thus increasing their profitability. Special mention deserves the PhD Thesis foreseen within the project and which will be carried out by the newly contracted researcher (this project applies to 1 FPI position).

Regarding the scientific diffusion, the time schedule specifies which expected deliverables should be in the form of contributions to conferences and/or journal papers (P), or technical and internal reports (T). The target national and international conferences cover areas like coastal, ocean and atmospheric sciences (*Coastal Sediments* 2011, *Coastal Dynamics* 2013, annual *Plinius* EU meetings on Mediterranean storms, WISE meeting from 2011, *Waves in Shallow Environments* WAVES 2012, *International Conference on Coastal Engineering* ICCE 2012 and on, *River, Coastal and Estuarine Morphodynamics* RCEM-2013, annual meetings of the CIESEM, and 2011 and 2013 editions of the *Jornadas Españolas de Puertos y Costas*), and Geophysics and earth sciences (annual meetings of the *European Geosciences Union*---EGU---, annual meetings of the *International Association for Mathematical Geosciences*---IAMG---) all of them well-recognised and established conferences. Target journals for our contributions are counted among the best on the areas of theoretical developments and applications of oceanographic operative forecast, risk assessment, statistics and environmental modelling, like: *Coastal Enginering*, *Journal of Marine Systems*, *Applied Ocean Research*, *Journal of Waterways, Port, Coastal and Ocean Engineering, Natural Hazard and Earth System Science, Stochastic Environmental Research and Risk Assessment, Journal of Physical Oceanography, Journal of Geophysical Research, Journal of Physical Mechanics,* and *Ocean and Coastal Management.* Those deliverables *a priori* suitable for submission as papers in journals and conference communications are marked in the time schedule with a P. The rest are considered as internal reports, and marked with a T.

About dissemination to the population, we plan some general contributions with the most striking results through all sorts of supports, including our web page, news on the press and TV documentaries, using the UPC news services. The LIM-CIIRC has an extensive experience on this issue.

6. BACKGROUND OF THE GROUP
(In the case of a coordinated project the topics 6. and 6.1. must be filled by each partner)

- **Indicate the previous activities and achievements of the group in the field of the project:**
  If the project is related to other previously granted, you must indicate the objectives and the results achieved in the previous project. If the project approaches a new research field, the background and previous contributions of the group in this field must be indicated in order to justify the capacity of the group to carry out the project.

The COVARIANCE project is devised as a follow-up of the RIMA project, also coordinated by the LIM-CIIRC/UPC. In few words, the RIMA project aimed at obtaining small-scale and high-resolution wave and current operative models, suitable for risk assessment and management. In RIMA it was concluded (as by other researchers, like Tri+09) that the present day models will not provide better forecasts without being fed with forcing terms at the same level of detail desired for the output. COVARIANCE aims at covering that issue with data assimilation.

The LIM-CIIRC/UPC Group has been working for more than 20 years on the physical component of coastal oceanography, including specifically wave and circulations fields, the resulting transport and their implications for harbour and coastal engineering. The group expertise includes field measurements (where LIM is responsible for the scientific management of the XIOM network of coastal oceanographic instruments), large scale laboratory research (where LIM is responsible for the CIEM large scale flume which is a large scale facility of the European Union since 1996 and an ICTS since 2005) and numerical simulations (where CIIRC and LIM have jointly developed the operational predictions for waves together with the Catalan Meteorological Services or for currents together with *Puertos del Estado – Agencia Española de Meteorología*).

The experience gained by combining the 3 approaches has resulted in numerous papers and communications dealing with the models' performance in the North Western Mediterranean, in the Cantabric and Atlantic coasts and even some applications in Antartica and the Dutch North Sea Coast. We have also contributed to the statistical characterization of oceanographic (weather and climatic) variables in the framework of passed (e.g. Floodsite) and present (e.g. CIRCE) EU Research Projects. The same applies to the operational capabilities for the Catalan coastal sea, where the LIM and CIIRC groups have been involved in several projects (eg. MFSPP, MFSTEP, and ESEOO) dealing with the improvement of monitoring and forecasting skills. In the framework of these projects, and related to the new research lines, the LIM-CIIRC group has implemented a data assimilation system well suited for coastal circulation in a 3D numerical model of the Catalan coast. We have selected the SEQUOIA data assimilation system, with an analysis kernel based on a reduced order optimal interpolation scheme [Jor05]. This research project aims at capitalizing and extending this experience.

We have also contributed to the more in depth theoretical aspects of wave/current coupling as illustrated by the work done in the recently finished EU Research Project Marie, coordinated by Professor Sánchez-Arcilla, coordinator of this proposal. The application of the newly derived terms for different meteo-oceanographic conditions is the subject of the recently approved EU research project FIELD_AC, also coordinated by Professor Sánchez-Arcilla. FIELD_AC also considers data assimilation, but it deals with open sea conditions and assimilation of satellite and airborne image information, whereas COVARIANCE covers local instrumentation along the coast.

6.2 PUBLIC AND PRIVATE GRANTED PROJECTS AND CONTRACTS OF THE RESEARCH GROUP

Indicate the project and contract grants during the last 5 years (2004-2008) (national, regional or international)

Include the grants for projects under evaluation

Title of the project or contract	Link with this proposal (1)	Principal Investigator	Budget (€)	Funding agency and project reference		Project period
ESTUDIO INTEGRAL DE UN CAÑON SUBMARINO EN EL MEDITERRÁNEO OCCIDENTAL (CAÑON DE BLANES):APLICACIÓN A LA EXPLOTACIÓN DE LA GAMBA ROSADA	1	MANUEL ESPINO INFANTES	138,000.00	MINISTERIO CIENCIA TECNOLOGIA	DEREN2002-04556-Yc02-01	11/2002 - 10/2005
DESARROLLO DE UN MODELO NUMÉRICO DE TRANSPORTE BIOFÍSICO PARA LA GESTIÓN DE RECURSOS PESQUEROS. APLICACIÓN AL GOLFO DE VIZCAYA.	1	MANUEL ESPINO INFANTES	6,900.00	MINISTERIO DE CIENCIA Y TECNOLOGIA	REN2003-09686-C03-03	12/2003 - 12/2004
AJUT ARCS 2003 - 3RD. IAHR SYMPOSIUM ON RIVER, COASTAL AND ESTUARINE MORPHDYNAMICS	3	AGUSTIN SANCHEZ-ARCILLA	3,000.00	GENERALITAT DE CATALUNYA	2003ARCS00114	07/2003 - 03/2004
TRASEDVE-TRANSPORTE DE SEDIMENTO A VARIAS ESCALAS EN EL MEDITERRANEO. IMPLICACIONES PARA EVOLUCION COSTERA.	1	JOSE A. JIMENEZ QUINTANA	41,319.58	DGESIC - DIRECCION GENERA	MAR98-0691-CO2-01	09/1998 - 09/2001
AJUST PER POTENCIAR I DONAR SUPORT ALS GRUPS DE RECERCA	2	AGUSTIN SANCHEZ-ARCILLA	23,439.47	G.C.DIRECCIÓ GENERAL DE R	2001SGR00245	12/2002 - 12/2004
RCEM 2003-3RD IAHR SYMPOSIUM ON RIVER, COASTAL AND ESTUARINE MORPHODYNAMICS	3	AGUSTIN SANCHEZ-ARCILLA	12,000.00	MINISTERIO DE CIENCIA Y T	REN2002-12151-E	04/2004 - 04/2005
ESTUDIO INTEGRAL DE UN CAÑON SUBMARINO EN EL MEDITERRANEO OCCIDENTAL.APLICACIÓN A LA EXPLOTACIÓN DE LA GAMBA ROSADA.	2	MANUEL ESPINO INFANTES	39,600.00	MINISTERIO DE CIENCIA Y T	REN2002-10796-E-MAR	05/2003 - 05/2004
AJUT ARCS 2005 - 5TH INTERNATIONAL CONFERENCE ON COASTAL DYNAMICS 2005	3	AGUSTIN SANCHEZ-ARCILLA	3,000.00	GENERALITAT DE CATALUNYA	2005 ARCS1 00243	04/2005 - 04/2005
SERVEI 5TH INTERNATIONAL CONFERENCE ON COASTAL DYNAMICS 2005 4-8/04/05	3	AGUSTIN SANCHEZ-ARCILLA	4,988.00	MINISTERIO MEDIO AMBIENTE		04/2005 - 06/2005
UNESCO-PROPUESTA OCEANOS	3	AGUSTIN SANCHEZ-ARCILLA	4,000.00	UNESCO	UNESCO	11/2000 - 12/2001
CONVENIO DE COLABORACIÓN ENTRE EPPE, APB, APT Y LA UPC PARA EL DESARROLLO DE UN PROGRAMA DE CONTROL DE LA CALIDAD DEL AGUA EN PUERTOS	1	AGUSTIN SANCHEZ-ARCILLA	87,928.00	ENTE PUBLICO DE PUERTOS D	EPPE/APB/APTARRA	05/2002 - 11/2005
INFLUENCIA DE LA REFLEXIÓN EN LA ESTABILIDAD Y REBASE DE LOS DIQUES EN TALUD (2ª FASE).	3	AGUSTIN SANCHEZ-ARCILLA	53,877.36	ENTE PUBLICO DE PUERTOS D		01/2003 - 06/2004
ESTUDI DELS CAIXONS DEL NOU DIC DE MARTELL DEL PORT ESPORTIU DE SANT FELIU DE GUÍXOLS.	3	JOAN PAU SIERRA PEDRICO	8,093.02	OTROS- PARTICULAR		01/2004 - 02/2004
ESTUDI DE LA DINÀMICA DEL LITORAL A CALAFELL.	3	JOSE A. JIMENEZ QUINTANA	18,560.00	AJUNTAMENT CALAFELL		03/2005 - 05/2005
GESTIÓ I MANTENIMENT DE LA XARXA D'INSTRUMENTS OCEANOGRÀFICS I METEOROLÒGICS AL LITORAL CATALÀ 2005	1	AGUSTIN SANCHEZ-ARCILLA	210,000.00	GENERALITAT DE CATALUNYA		01/2005 - 12/2005
MANTENIMENT I GESTIÓ DE LA XARXA D'INSTRUMENTS OCEANOGRÀFICS I METEOROLÒGICS AL LITORAL CATALÀ 2004	1	AGUSTIN SANCHEZ-ARCILLA	135,636.00	GENERALITAT DE CATALUNYA		01/2004 - 12/2004
MANTENIMENT I GESTIÓ DE LA XARXA D'INSTRUMENTS OCEANOGRÀFICS I METEOROLÒGICS AL LITORAL CATALÀ 2005	1	AGUSTIN SANCHEZ-ARCILLA	209,997.12	GENERALITAT DE CATALUNYA		01/2005 - 12/2005

CONVENIO DE COLABORACIÓN ENTRE EPPE, APB, APT Y LA UPC PARA EL DESARROLLO DE UN PROGRAMA DE CONTROLS DE LA CALIDAD DEL AGUA EN PUERTOS	1	AGUSTIN SANCHEZ-ARCILLA	87,928.00	AUTORIDAD PORTUARIA DE TA		05/2002 - 11/2005
ESTUDIO DE LA PLATJA DE SA RIERA.	3	JOSE A. JIMENEZ QUINTANA	10,440.00	INFORMES Y PROYECTOS, S.A		07/2005 - 08/2005
CONVENI DE COL.LABORACIÓ ENTRE UPC I EL DEPARTAMENT DE POLÍTICA TERRITORIAL I OBRES PÚBLIQUES SOBRE AMPLIACIÓ DE LA XARXA D'INSTRUMENTAL	1	AGUSTIN SANCHEZ-ARCILLA	265,000.00	GC-DEPT.POLITICA TERRITOR		12/2004 - 12/2005
ACUIMOD- UNA HERRAMIENTA PARA LA GESTIÓN DE LA ACUICULTURA MARINA.	1	MANUEL ESPINO INFANTES	58,526.98	PANGEA MEDITERRÁNEO, S.L		01/2003 - 01/2004
MANTENIMENT I DESENVOLUPAMENT DE LA PREDICCIÓ D'ONATGE A CATALUNYA. APROPAMENT COSTANER I PORTUARI.CONVENI SERVEI DE METEOROLÒGIC DE CATALUNYA 2004	1	AGUSTIN SANCHEZ-ARCILLA	47,000.00	SERVEI METEOROLÒGIC DE CATALUNYA		02/2004 - 12/2004
MANTENIMENT I DESENVOLUPAMENT DE LA PREDICCIÓ D'ONATGE A CATALUNYA. APROPAMENT COSTANER I PORTUARI. 2005	1	AGUSTIN SANCHEZ-ARCILLA	47,000.00	SERVEI METEOROLÒGIC DE CATALUNYA		04/2005 - 12/2005
ELABORACIÓN DEL PLAN DIRECTOR DE REMODELACIÓN DEL FACHADA MARÍTIMA DE SANTA CRUZ DE LA PALMA	3	AGUSTIN SANCHEZ-ARCILLA	73,000.00	AMP ARQUITECTOS S.L.		03/2004 - 09/2004
CONVENI PER A L'ESTUDI DE FACTIBILITAT D'UN NOU PORT ESPORTIU A CAP SALOU.UPC- SR. JOAQUIM OLIVA.	3	AGUSTIN SANCHEZ-ARCILLA	9,442.40	JOAQUIM OLIVA VALLS		04/2004 - 07/2004
CONV.DE COL.LABORACIÓ ENTRE L'AJUNTAMENT DE SITGES I EL CENTRE INTERNACIONAL D'INVESTIGACIÓ DELS RECURSOS COSTANERS PER A LES PLATJES	3	AGUSTIN SANCHEZ-ARCILLA	11,368.00	AJUNTAMENT DE SITGES	EXP007/04-MA	06/2004 - 12/2004
ESTUDIO DEL ESTADO ACTUAL DE LOS SISTEMAS DUNARES DE CORRALEJO Y JANDIA (FUERTEVENTURA). IDENTIFICACIÓN DE PROBLEMAS Y PROPUESTAS	3	JOSE A. JIMENEZ QUINTANA	63,800.00	MINISTERIO MEDIO AMBIENTE		05/2005 - 11/2005
ESTUDI D'OPTIMITZACIÓ DE LES INSTAL.LACIONES DE GÀBIES SURANTS PER AL CULTIU DE PEIXOS A MAR OBERT.	2	AGUSTIN SANCHEZ-ARCILLA	22,500.00	G.C.DEPARTAMENT D'AGRICUL		06/2005 - 12/2005
CONV.PER AL DISSENY DE L'ESPIGÓ DE PROTECCIÓ D'UN INTERCEPTOR A LA PLATJA DE MATARÓ.	3	AGUSTIN SANCHEZ-ARCILLA	2,320.00	COPCISA, S.A		01/2005 - 03/2005
ESTUARIES AND COASTAL AREAS BASIS AND TOOLS FOR A MORE SUSTAINABLE DEVELOPMENT	2	AGUSTIN SANCHEZ-ARCILLA	200,395.00	COMUNIDAD EUROPEA	ICA4-CT-2001-10027	01/2002 - 12/2004
COASTVIEW VIDEO MONOTORING OF LITTORAL PROCESSES IN SUPPORT OF COASTAL-ZONE MANAGEMENT.	2	JOSE A. JIMENEZ QUINTANA	125,188.00	COMUNIDAD EUROPEA	EVK3-CT-2001-00054	04/2002 - 03/2005
HYDRALAB-II.RESEARCH INFRASTRUCTURE COOPERATION NE TWORK HYDRALAB II. IMPROVING THE HUMAN RESEARCH PO TENTIAL AND THE SOCIO-ECONOM	2	AGUSTIN SANCHEZ-ARCILLA	17,208.23	COMUNIDAD EUROPEA	HPRI-CT-1999-40008	03/2000 - 02/2004
DELOS ENVIRONMENTAL DESIGN OF LOW CRESTED COASTAL DEFENCE STRUCTURES.	2	AGUSTIN SANCHEZ-ARCILLA	109,000.00	COMUNIDAD EUROPEA	EVK3-CT-2000-00041	02/2001 - 01/2004
WAVE FLUME CANAL DE INVESTIGACIÓN Y EXPERIMENTACIÓN MARITIMA II	2	AGUSTIN SANCHEZ-ARCILLA	125,000.00	COMUNIDAD EUROPEA	HPRI-CT-2002-00195	02/2003 - 07/2004
LARGE SCALE OVERTOPPING TESTS.	2	AGUSTIN SANCHEZ-ARCILLA	40,000.00	AALBORG UNIVERSITY ENGINE		04/2005 - 09/2005
TREBALL DE MODEL DE CORRENTS PER SIMULAR LA RENOVACIÓ DE L'AIGUA EN EL PROJECTE DE LA MARINA DE SANT JAUME D'ENVEJA	2	JOAN PAU SIERRA PEDRICO	3,190.00	INURSA-INFRAEST Y URBANISMO, S.A		03/2004 - 04/2004
SERVICIOS VARIOS-TALLER D'ENGINYERIA	3	JOSE A. JIMENEZ QUINTANA	17,890.94	TALLER D'ENGINYERIA AMBIENTAL		01/2004 - 12/2004
SERVEIS NECESSARIS PER A L'ELABORACIÓ D'UN ESTUDI DE MODELITZACIÓ SOBRE LA DINÀMICA, TRANSPORT I ACUMULACIÓ DE SÒLIDS FLOTANTS AL	1	MANUEL ESPINO INFANTES	27,874.80	AGÈNCIA CATALANA DE L'AIG	EXPE CT05000386	05/2005 - 08/2005

COLABORACIÓN ESTUDIO NUMÉRICO DEL IMPACTO EN LA RÍA DE HUELVA DE VERTIDOS DE CENTRALES TÉRMICAS	1	MANUEL ESPINO INFANTES	6,000.00	INSTITUT CIÈNCIES DEL MAR		12/2003 - 12/2005
ESTUDI I DESENVOLUPAMENT D'UN MODEL DE DISPERSIÓ DE CONTAMINANTS MARINS.	1	AGUSTIN SANCHEZ-ARCILLA	20,300.00	GC-DIRECCIO G.EMERGÈNCIES		03/2005 - 08/2005
IMPLEMENTACIÓ D'UN SISTEMA OPERACIONAL DE PREVISIÓ DE CONTAMINACIÓ EN EL CECAT.	1	AGUSTIN SANCHEZ-ARCILLA	14,500.00	GC-DIRECCIO G.EMERGÈNCIES		03/2005 - 08/2005
COMPRA DE BOIES LAGRANGIANAS	1	AGUSTIN SANCHEZ-ARCILLA	4,036.80	GC-DIRECCIO G.EMERGÈNCIES		11/2004 - 11/2005
INFORME SOBRE EL ESTUDIO DE REBASE DE LA MARINA DE PALAMÓS	3	JOAN PAU SIERRA PEDRICO	2,039.86	NAUTIC PALAMOS, S.A		11/2004 - 01/2005
MODELIZACIÓN MARINA EN EL MARCO DEL PROYECTO IMPRES	3	MANUEL ESPINO INFANTES	26,912.00	AZTI-TECNALIA-UNIDAD DE		11/2004 - 10/2005
REDACCIÓN DEL PLAN DE ACTUACIONES EN LA COSTA DEL DELTA DEL EBRO PARA EL AÑO 2005 (CONJUNTAMENTE CON TALLER DE INGENIERIA AMBIENTAL)	3	JOSE A. JIMENEZ QUINTANA	4,988.00	MINISTERIO MEDIO AMBIENTE		03/2005 - 12/2005
ASSESSORIA TÈCNICA: VALORACIÓ TÈCNICA DE DOCUMENTACIÓ REFERENT ALS DANYS OCORREGUTS EN EL DIC PRINCIPAL I EN EL MORRO NORD (TEMPOR	3	XAVIER GIRONELLA COBOS	4,654.85	UTE NOVA BOCANA		11/2005 - 12/2005
DESARROLLO Y OPTIMIZACIÓN DE TÉCNICAS PARA GESTIONAR LOS VERTIDOS DE AGUAS RESIDUALES DE EMISARIOS SUBMARINOS	1	JOAN PAU SIERRA	54,050.00	MINISTERIO DE CIENCIA Y TECNOLOGIA	REN2003-07585-C02-01	12/2003 12/2006
GESTIÓN Y MANTENIMIENTO DE LA RED DE INSTRUMENTAL OCEANOGRÁFICO Y METEOROLÓGICO DE LA GENERALITAT DE CATALUNYA	1	AGUSTÍN SÁNCHEZ-ARCILLA	241,938.00	GENERALITAT DE CATALUNYA		01/2006 12/2006
MEDITERRANEAN OCEAN FORECASTING SYSTEM: TOWARD ENVIRONMENTAL PREDICTIONS	1	AGUSTÍN SÁNCHEZ-ARCILLA	73,000.00	COMUNIDAD EUROPEA	EVK3-CT-2002-00075	03/2003 02/2006
SISTEMA ESPAÑOL DE OCEANOGRAFIA OPERACIONAL: MODELADO OCEANOGRAFICO Y DE VERTIDOS DE PETROLEO	1	AGUSTÍN SÁNCHEZ-ARCILLA	68,885.00	MINISTERIO DE CIENCIA Y TECNOLOGIA	VEM2003-20577-C14-05	12/2003 12/2006
CONVENIO TORMENTAS DE OLEAJE EN LA COSTA CATALANA. VARIABILIDAD, TENDENCIAS Y CLIMAS MEDIO Y EXTREMO	1	AGUSTÍN SÁNCHEZ-ARCILLA	44,660.00	DEPARTAMENT DE POLITICA TERRITORIAL- GC		12/2005 12/2007
CONVENIO DE COLABORACIÓN ENTRE LA DIRECCIÓN GENERAL DE COSTAS, INTEGRADA EN LA SECRETARÍA DEL TERRITORIO Y LA BIODIVERSIDAD DEL MINISTERIO DE MEDIO AMBIENTE Y LA UPC PARA LA PRESTACIÓN DE ASISTENCIA CIENTÍFICA AL PLAN DE TRABAJOS DE LA DIRECCIÓN GENERAL DE COSTAS	1	AGUSTÍN SÁNCHEZ-ARCILLA	147,491.68	MINISTERIO MEDIO AMBIENTE		11/2005 10/2007
MARIE CURIE ACTIONS MODELLING AND ASSIMILATION FOR ROFL ENVIRONMENTS. LIMITS OF PREDICTIBILITY	1	AGUSTÍN SÁNCHEZ-ARCILLA	264,866.00	COMUNIDAD EUROPEA	MTKD-CT-2004-014509	03/2005 02/209
PREVISIÓN DE OLEAJE EN EL MEDITERRÁNEO ESPAÑOL. LIMITACIONES, ERRORES Y PROPUESTAS DE MEJORA	1	AGUSTÍN SÁNCHEZ-ARCILLA	92,575.00	MINISTERIO DE CIENCIA Y TECNOLOGIA	REN2002-03415	03/2003 03/2006
FLOODSITE. INTEGRATED FLOOD RISK ANALYSIS AND MANAGEMENT METHODOLOGIES	2	AGUSTÍN SÁNCHEZ-ARCILLA	206,014.08	COMUNIDAD EUROPEA	GOCE-CT-2004-505420	03/2004 02/2009
DESARROLLO Y VALIDACIÓN DE UN MÉTODO DE VALORACIÓN DEL RECURSO PLAYA COMO AYUDA A LA GESTIÓN INTEGRADA DE ZONAS TURISTICAS COSTERAS	2	JOSÉ A. JIMÉNEZ-QUINTANA	60,375.00	MINISTERIO DE CIENCIA Y TECNOLOGIA	REN2003-09029-C03-01	12/2003 12/2006
ACCIÓN COMPLEMENTARIA - VIII JORNADAS ESPAÑOLAS DE INGENIERÍA DE COSTAS Y PUERTOS	3	JOSÉ A. JIMÉNEZ-QUINTANA	6,000.00	MINISTERIO EDUCACIÓN Y CIENCIA	CTM2004-21543-E	09/2005 12/2006

ACCIÓN COMPLEMENTARIA - 5TH INTERNATIONAL CONFERENCE ON COASTAL DYNAMICS 2005	3	AGUSTÍN SÁNCHEZ-ARCILLA	12,000.00	MINISTERIO EDUCACIÓN Y CIENCIA	CTM2004-21603-E/MAR	09/2005 12/2006
WATER QUALITY AND SUSTAINABLE AQUACULTURE: LINKS AND IMPLICATIONS	1	AGUSTIN SANCHEZ-ARCILLA	150,000.00	COMUNIDAD EUROPEA	C015105(INCO)	01/2006 06/2007
INTEGRATED INFRASTRUCTURE INITIATIVE HYDRALAB-III	2	AGUSTIN SANCHEZ-ARCILLA	675,600.00	COMUNIDAD EUROPEA		03/2006 03/2010
DESARROLLO DE UN MODELO NUMERICO PREDICTIVO DEL COMPORTAMIENTO DE HUEVOS Y LARVAS DE ESPECIES COMERCIALES EN EL GOLFO DE VIZCAYA CON APLICACIONES A LA GESTION DE RECURSOS	2	MANUEL ESPINO INFANTES	124,950.00	MINISTERIO DE EDUCACION Y CIENCIA		12/2005 12/2008
HACIA UNA REDUCCIÓN DE RIESGOS MARÍTIMOS USANDO MODELADO DE ALTA RESOLUCIÓN. (RIMA)	1	AGUSTIN SANCHEZ-ARCILLA	125114.02	MINISTERIO DE EDUCACION Y CIENCIA	TRA2006-05132	10/2006 3/2010
FLUXES, INTERACTIONS AND ENVIRONMENT AT THE LAND-OCEAN BOUNDARY. DOWNSCALING, ASSIMILATION AND COUPLING (FIELD_AC)	1	AGUSTIN SANCHEZ-ARCILLA	3309417.00	COMUNIDAD EUROPEA	FP7-GA-2009-1	1/2010 12/2012

(1) Write 0, 1, 2 or 3 according to: 0 = Similar project; 1 = Very related; 2 = Low related; 3 = Unrelated.
(2) All reported pojects are funded.

7. TRAINING CAPACITY OF THE PROJECT AND THE GROUP
(In the case of Coordinated Projects this issue must be filled by each partner)

- This title must be filled only in case of a positive answer to the corresponding question in the application form.
- Justify that the group is able to receive fellow students (from the Suprograma de Formacion de Investigadores) associated to this project and describe the training capacity of the group. In the case of coordinated projects, each subproject requesting a FPI fellowship must fill this issue.
- Note that all necessary personnel costs should be included in the total budget requested. The available number of FPI fellowships is limited, and they will be granted to selected projects as a function of their final qualification and the training capacity of the groups.

The validation of assimilation in wind/wave/current models, as described in the COVARIANCE project, using the advanced numerical and statistical tools and intensive field observations derived from this research will allow the training of a PhD student in wave spectrum data assimilation, covering the physical aspects of wave generation (Goal 6.1) and the more statistical aspects of conditioning algorithms (corresponding to G2 and G3).

The educational capacity of the COVARIANCE group and, in particular, the LIM/UPC (cordinator) is supported by the professional background of the research staff (justified by the enclosed curriculum vitae). The combination of university centres and research institutions (*Barcelona Supercomputing Center*, or *Institut de Ciències del Mar-CSIC*) with operational centres (as partners such as *Servei Meteorologic de Catalunya*) ensure the scientific and practical aspects of this education. In particular the co-ordinating institution (LIM/UPC) is responsible (together with the *Institut de Ciències del Mar* and University of Barcelona) for a PhD programme on Marine Sciences which received from the beginning the Quality Award of the Ministry of Education in Spain and which has been active for more than 20 years and has produced more than 100 PhD thesis within that period. The UPC is also coordinating 2 master programmes in Harbour Engineering and Management and Coastal Engineering and Management, which have been working for almost 15 and 10 years respectively and which have produced within that period more than 25 master theses. Moreover, this group is also the leading Spanish partner of COMEM, an ERASMUS-MUNDUS Master Program coordinated by the TU Delft, which has been going on for 3 years with increasing success. This together with the teaching activities within the Civil Engineering School of Barcelona, where more than 80 master theses have been directed in just the last 5 years, illustrate the educational capacity of this group.

APPENDIX.

TASK SCHEDULE