HAVVARSEL

Personalized ocean forecasts in a two-way data flow system

SINTEF DIGITAL (SD), INSTITUTE OF MARINE RESEARCH (IMR), NORWEGIAN METEOROLOGICAL INSTITUTE (MET)

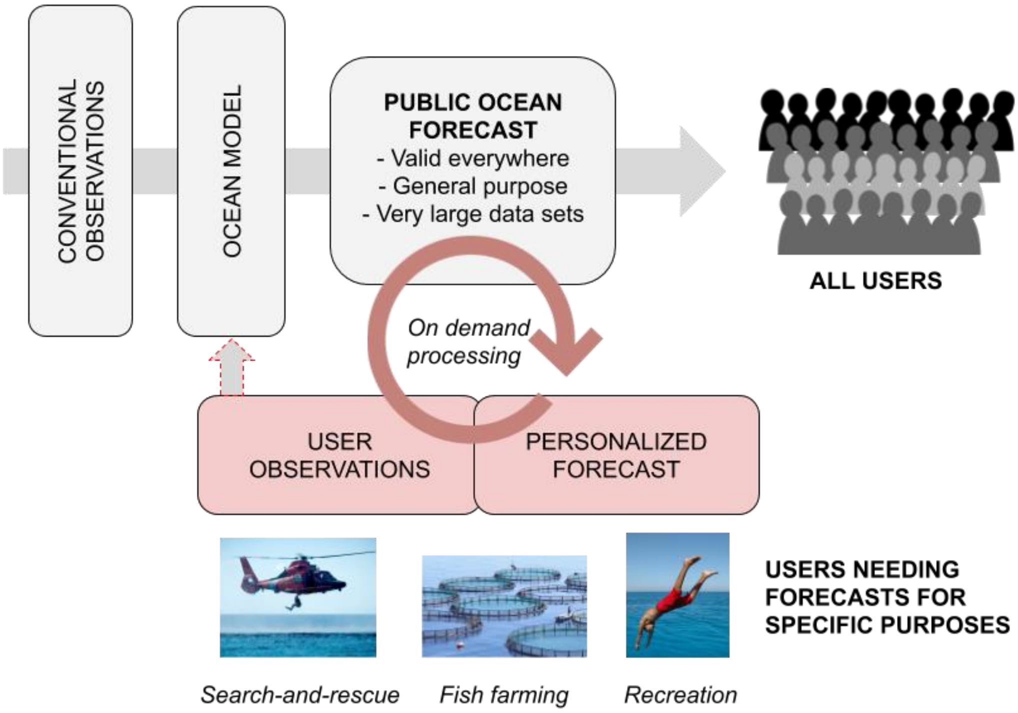

Fig 1. The traditional ocean forecast value chain (in grey) and the proposed additional components (in red). Todays production of ocean forecasts is a scheduled operation with typical cycles of one day, using geophysical models that generate very large data sets. We aim to tailor the forecasts to users' specific needs by combining dedicated user observations with a subset of the traditional forecast products. Public-private partnerships and citizen observations are becoming increasingly relevant also for the conventional forecast models, here indicated by the dashed arrow, which means that the ability to handle non-standard data streams from non-standard sensors are becoming increasingly important for the responsible government agencies.

1. Excellence

In this project we will improve technological and methodological solutions for uploading, processing, and displaying oceanographic data for citizens, media, marine industry, and maritime management. *Our long-term ambition is to enable users to get local personalized ocean forecasts, as well as easy access to the general data and statistical information about the ocean.* Figure 1 illustrates how the proposed project fits in with the conventional ocean forecast value chain, by adding a fast two-way interaction with our users. The users provide dedicated observations, and in turn receive tailored forecasts produced by post-processing methods that combine these observations with traditional ocean model output.

Our main objective is to build competence and prepare for the next generation ocean forecast services. While some parts of the proposed work is based on advanced methods, other parts are quite simple. We will focus on testing the entire ocean forecast value chain as indicated in Fig. 1. To conduct this we propose three demonstrators, each connected to a different user group. These demonstrators serve as triggers for project objectives and research questions, and show a clear path from project outcomes to value for end users and will be valuable steps on the path towards reaching our main objective.

Ocean "weather service" demands very large computer resources. Furthermore, methods and computer capacity for including more irregular observations in the forecasts by assimilation have improved. Combined with the development of cheaper instrumentation and better IoT and cloud technologies, that now is accessible for local industry and public, gives a window of opportunity to develop locally more precise forecasts directed towards a wide set of user groups. The challenges given in the RCN/ICTpluss programme and specific call text are addressed in this project with a multidisciplinary approach towards IoT (enabling users to provide observations) and digital interfaces (establishing a service for personalized forecasts). We will answer to the medium risk/ time horizon challenge defined by RCN where we intend to increase the general knowledge and build stronger cross disciplinary competence at partners. Further, it relates to the increasing need for better digital services to meet societal challenges within marine sectors.

1.1 State of the art, knowledge needs and project objectives

The ocean has always been of paramount importance for Norway, and today 80% of the population live within 10 km of our long coastline. A large portion of Norwegian industry uses or operates in the ocean, and this gives rise to a strong interest and need for information. Internet of things (IoT) and development of smart and inexpensive sensors have taken measurements of ocean parameters from the research institutions and out to the public. Today several companies monitor their water intake and the local surroundings, fishermen and recreational fishers have sensors on their fishing gear, and interested citizens takes measurements for fun. Unfortunately, these measurements are mostly neither stored nor processed, but simply discarded after being displayed to a single user. At the same time, one of the main challenges for ocean forecasting is the limited number of observations available for the operational models (Moore et al., 2014; Haiden et al., 2018).

Today, ocean forecasts for Norwegian waters are produced operationally by MET. The forecasts are made using ocean circulation models that are very costly in terms of supercomputing resources, and therefore are run using fixed cycles of typically one day. The national model configurations are developed in collaboration with partners in Norway and abroad, in particular the IMR, who in turn uses the modelling systems to assess the state of ecosystems, connectivity, spread of salmon lice, etc. Forecast quality strongly depends on the accuracy of the model initial conditions, and hence a lot of effort goes into using observations from high accuracy regular monitoring systems to correct these, employing state-of-the-art data assimilation methods (e.g. Sperrevik et al., 2018). The impact of the various observation platforms may be quantified, for example, in-situ temperature and salinity measurements, satellite sea surface temperature, and HF radars and their respective importance when modelling the coastal ocean (Christensen et al., 2018). New technological development makes it possible to improve the forecast services by including more irregular observations from e.g. companies, fishermen and the public. There are great challenges by assimilating such observations into the ocean model, such as different and non-standard formats used for the same parameters, irregular sampling in time and space, little known data quality, data security and GDPR compliance. However, the potential benefits for successfully doing so are great, as demonstrated in recent data assimilation experiments (RCN projects GLIDER, CIRFA).

When designing the future ocean forecast services it is not enough to simply prepare for ingesting user observations in the ocean forecast value chain. There are several reasons, but two in particular: (1) Our coastal ocean forecast model, with its sub-kilometre resolution, provides much detail, but the coastal topography is incredibly complex and the physical conditions may vary significantly over very small distances. At any specific place, the local conditions obviously correlate with the large scale conditions, which enables efficient methods for statistical calibration (e.g. Wilks, 2011) provided local observations are available. Such methods have been used in operational meteorology for a long time (e.g. Homleid, 1995), but is little used in ocean forecasting. (2) Many problems faced by our users are multidisciplinary and require more information than can be provided by the forecast model. One example is the oxygen content, which is highly relevant for fish farmers but not a standard output variable in the ocean model. Oxygen content is a complex function of physical (ocean currents, upper ocean turbulence), biological (sources and sinks at various trophic levels) and external factors (e.g. the quantities with which the fish are fed). A subset of the relevant model parameters may be combined with dedicated observations of oxygen content and information about feeding routines to provide estimates of how oxygen content will develop in the next few days.

Another important aspect is that the ocean forecasts provide input to drift trajectory models. Examples include trajectory predictions for search-and-rescue support, oil spill drift mitigation, and ship drift simulations. MET uses the OpenDrift framework for trajectory modelling (Dagestad *et al.*, 2018), which takes input from the coastal ocean forecast model for the currents. In the GPU Ocean project (RCN), a complementary approach, with large ensembles of simplified ocean models has been tested (Holm et al., 2019a). Such ensembles, combined with nonlinear data assimilation methods, have been implemented efficiently on GPUs for the purpose of predicting drift trajectories (Holm et al., 2019b). The nonlinear data assimilation methods have previously been restricted to low-dimensional problems, but with recent development they have become relevant for high-dimensional problems (Vetra-Carvalho et al., 2018; van Leeuwen et al., 2019), such as the oceanic drift applications we consider here. It is still a challenge to express error correlations associated with unresolved physical processes, but a promising approach is to use machine learning, combining the dynamical model with data-driven correction terms (Watson, 2019).

1.2 Novelty and ambition

Future ocean forecasting services need to take advantage of user observations, and efficiently combine them with the conventional forecasts using post-processing method that is most appropriate for a specific purpose. IMR and MET, with their strength in ocean observations and modelling, are therefore teaming up with SINTEF DIGITAL, whose Mathematics and Cybernetics department has strong expertise in numerical simulation in combination with big data handling, machine learning and open-source software development. In addition, a large stakeholder group has been established consisting of important users (including leading media newspaper, aquaculture industry, tourist business and governmental coastal rescue and management bodies). Together, the consortium will develop their own competence bases, as well as exchange knowledge across institutions, to form a broader digital environment for data flow, big data and IoT issues needed to develop the future ocean information systems. For IMR and MET this fit well into their core institutional strategies.

The project will address the different challenges that need to be solved to establish such an interactive ocean forecasting service, with the aim of making prototypes towards the new components in IMR and MET operational suites.

1.3 Research questions, theoretical approach and methodology

The project addresses 4 main research questions:

1) How do we design the (two-way) dataflows and storage systems, in such a way that GDPR compliance is ensured?
2) How do we develop tailored mathematical models, in such a way that they give local forecasts?
3) How do we combine user data with data assimilation and machine learning in such a way that they improve local forecast quality?
4) How do we show the results, in such a way that they are attractive for the stakeholder?

In order to address these four questions, the project is organized into four work packages. Further, three demonstrator cases have been picked, that both addresses a spread in stakeholders and contain different challenges related to the three main questions.

WP1 focuses on the dataflows. We will collect user observations and adapt the operational processing chain to allow for on demand delivery of personalized forecasts. Users/data providers may require anonymity, or deletion of every contributed data entry (cf. GDPR and the "right to be forgotten": location and type of observation may be implicit from forecast impact and hence every trace of the data may not be easily removed). Other outstanding challenges include implementation of quality controls, bias corrections, estimation of errors of representativeness, a wide range of formats for interpretation/conversion.

In WP2, the project will push the research front on localized ocean forecasts. This will be done by implementing lightweight models suitable for drift applications, and combine these with user-provided data from WP1 using nonlinear data assimilation methods in order to produce ocean current ensembles. The work in WP2 will result in prototypes for the demonstrators in WP3, which are used to define the scope of this WP. The project PhD-student will have main focus on this WP, and there will be close cooperation with Prof. Eidsvik at NTNU.

In WP3 we will bring the forecasts back to the user. We will develop three prototypes that link together the results from the two first work packages, directed towards three different segments of the intended user base: one government, one industry and one public. We will work closely to each set of stakeholders for each of these demonstrators, to ensure that the information is supplied in the way it will be needed.

WP4 is the overarching WP for project management, outreach and internal cooperation. We will interact with stakeholders representing governance, industry and the general public with the overall aim of designing the most useful forecast products.

In the different demonstrators, the complexity will vary depending on what the final goal is and where in the forecast value chain we need to put our main efforts. We therefore describe the demonstrators separately although the tasks are superficially similar between them:

Demonstrator I – Drift trajectory modelling for search-and-rescue (for Government Agency)

Background and users: Drift trajectory modelling in the ocean is important in a wide range of areas, e.g., oil spills, man-overboard, icebergs, plastic, lost shipping containers. As a prototype application we will focus on search and rescue operations (SAR), in which accurate and timely drift trajectory predictions are vital for determining the search area. Drift trajectory predictions are also essential for coordinating oil spill clean-up and in ensuring the safety of offshore installations. Further, for search of drowned persons the police need local on-demand trajectories.

Observations and methodology: Starting a drift trajectory simulation need at least one observation of the drifting object. Assimilation of multiple observations in time will improve the predictions, as will observations of the ocean current or parameters affecting the ocean currents. Based on currents, waves and wind from the forecast and a last-known position of the drifting object from the user, a drift trajectory prediction can be generated. By running an ensemble of drift simulations, the spread of the ensemble may be used to determine the extent of the search area. This prototype will be based on existing drift trajectory modelling tools at MET, both the operational OpenDrift (Dagestad et al., 2018) suite and the results from the ongoing GPU Ocean project (Holm *et al.*, 2019a; Holm *et al.*, 2019b). The first version of this prototype will only support passive drifters. We will continue research on this topic by further exploring two- or more-layered simplified models, assimilating observations other than drifter positions, and explore machine learning algorithms for better description of model error terms (Watson, 2019).

Demonstrator II – Salmon farm application (for industry)

Background and users: Open water aquaculture in Norway consists mostly of salmon fish farms and these are strongly dependent on the environmental conditions. The water temperature will have optimal ranges and critical thresholds, and the open pens with large amounts of fish will need a constant supply of oxygen rich water. Additionally, the environmental conditions, like winds, waves and currents, cannot exceed limits that potentially destroy the constructions and/or increase stress levels on the fish. Salmon farmers will benefit from getting information on the evolution of the environmental conditions for the next few days. Also, some prognosis of the evolution of water temperature the coming weeks and months will be useful. Furthermore, information on dispersion of water borne agents or diseases, either to their own farm for prevention or from their own farm for documentation purposes, can be highly relevant.

Observations and methodology: Many Aquafarms have permanent sensors that informs their control room about the in-cage and environmental conditions. Several has bought solutions that sends this information to a web service/cloud. User data will be downloaded to MET/IMR for further processing. Typical the data is temperature, salinity, oxygen and/or current, but can also include other biochemical sensors. Physical parameters will be ingested in the assimilative circulation model, and the results combined with statistical calibration methods (see also Demonstrator III) to better describe the local physical conditions. Due to the high number of parameters and large available data sets, we will also explore a more empirical approach by using machine learning methods (Reichstein et al., 2019). The data company SEARIS, are already involved in supplying the industry (e.g. Eide fjordbruk) with big data solutions, and have expressed a particular interest in our results.

Demonstrator III – Swimming temperature ("badetemperatur", for the general public)

Background and users: Temperatures in the upper few meters of the sea close to the coast experiences large short time variations. Several physical processes are involved (e.g. solar heating, wind driven on-shore and off-shore water, transports, retention areas in bays and shallow areas). Therefore, local prediction is extremely difficult. On the other side, there is a huge seasonal public interest for this information, especially the forecast options. Tourist industry and media have a need for more correct information to customers and readers, and waterfront hotels want to give these as a service to their guests. Also, industries have need of this information throughout the year to monitor such as water intake, welfare in fish farms and danger of sea ice generation.

Observations and methodology: There is a growing number of sensors from both moving and fixed platforms deployed at public beaches, hotels, sea farms and harbours. The use of such observations for data assimilation can be problematic due to errors of representativeness. For example, the temperature on a shallow beach that is unresolved in the model may vary several degrees from the nearest model grid point, which will typically represent deeper waters further out. In addition, the temperature in shallow areas may change with several degrees over just a few hours due to radiative forcing. Statistical calibration will be applied to several locations of stakeholders involved in the project. Common univariate methods will be applied (e.g. MOS, see Wilks, 2011) and evaluated. Periods with low score will be analysed in more detail to assess the need for more advanced, multivariate methods, that include e.g. wind speed and shortwave radiation.

Data management and GDPR

Data results will in general have open user licence, unless there are given limitation from data providers. Data will be available through MET and IMR servers and the national infrastructure NMDC, in addition to be available through the web modules. It will be a part of the project to evaluate related GDPR issues. The project will follow the institutions data- and GDPR policies during the work, and data management will follow the FAIR principles.

All simulation code developed in the project will be made available on Github as open source, and will be based on rapid prototyping and agile development. We will further apply best-practices for reproducible science, by publishing both the software and data used in scientific papers in appropriate open repositories, such as Zenodo.

2. Impact

2.1 Potential impact of the proposed research

Our vision is to build a web service, havvarsel.no, that can be used by all the people that need information about the state of the sea, following in the steps of the weather services such as yr.no and storm.no. However, we also want to go beyond. First by letting the operational modelled nowcast and forecasts easily available. Second, to make it easier to get access to statistical information, and the huge amount of our online- and historical observations. And third, lay the foundation for entrepreneurs to further develop modules and downstream services.

IMR and MET societal missions are not to build commercial products but rather to lay the foundation for marine industry development. The project will therefore only show the pathway forward through the three demonstrator and leave it for others to commercialise further products based on free access to the produced forecast. However, we see a very wide range of potential applications that can be initiated, such as within maritime transport (improved routes decision in bad weather; optimised fuel consumption due to better current information, safer guidance of large ships in shallow water by AIS and local current information); aquaculture (feeding under low current situations, preparedness for heavy ocean state of waves and currents and low oxygen /high temperature events); public (better forecasted swimming condition, better information or recreational fishing); better foundation for algae bloom warning systems; engineers needing information for structure designs (platforms, windmills, kay and harbour); sailing vessels along the coast; better decision tools for sudden accidents (ships in distress, oil spills); hazardous conditions for the fishing fleet. Further, creative workshops for students to develop their own ideas will be initiated, together with UiO.

2.2 Measures for communication and exploitation

The vision of the service havvarsel.no has a very wide user group potential, both upstream data suppliers and downstream data users. We address three specific, and quite different challenges, and through the pilot demonstrators show the broad scope of this project. Within each of these demonstrators dedicated stakeholders, that has confirmed willingness to participate in the project, will act as dialog partners for the project staff to ensure that their needs will be in line with the projects outcome. The communication will mostly be one-on-one, but the members of the stakeholder group will also be invited to the general assemblies to further influence on the project progress. Due to the feedback loop from supplying local data several of the stakeholders are both data suppliers and users of our results.

<u>Stakeholder group and contact persons (CP)</u>

1) *Hovedredningssentralen* (the national Joint Rescue Coordination Centre) has national responsibility in case of larger rescue operations. They are a user in our Search and rescue demonstrator (WP3, demonstrator I). Contact person: Rescue leader Raymond Prestøy
2) *Kystverket* (The Norwegian Coastal Administration) is the responsible authorities for maritime services and operation leader for oil spill mitigation. They are a user in our Search and Rescue demonstrator (WP3, demonstrator I). CP: Senior engineer Harald Åsheim.
3) *Police, Sør-Øst Politidistrikt,* need quick and easily accessible information on sea state, especially about currents and waves and possible trajectories. They are a user in our Search and Rescue demonstrator (WP3, demonstrator I). CP: Police captain Terje Sandik.

4) *SEARIS* with their Clarify platform is a software technology developer that works with Eide havbruk to streamline their information needs into an operational farm management tool. They will be a user in the aquaculture demonstrator (WP3, demonstrator II). CP: CEO Tore Norheim Hagtun.
5) *Eide Fjordbruk* is a major aquaculture farm company in Norway, and they have a high focus on utilizing new technology and information, among them both current meters and other oceanographic sensors. They are both data provider and user (through SEARIS) in our aquaculture demonstrator (WP3, demonstrator II). CP: Technical director Erlend Eide
6) *VG* is one of Norway's leading newspapers and part of Schibsted media house, with a range of digital services; and daily reporting of weather report through digital solutions. They will be a user in our swimming temperature demonstrator (WP3, demonstrator III). CP: Digital director Ola Stenberg
7) *Solstrand fjordhotell* is a local sea resort hotel that reports daily sea temperatures to their guests. They will be both a data provider and a user in our swimming temperature demonstrator (WP3, demonstrator III). CP: General manager Børrea Schau-Larsen.
8) *badevann.no* runs a series of sea temperatures buoys at popular Norwegian beaches, along with a presentation web site. They will be both a data provider and a user in our swimming temperature demonstrator (WP3, demonstrator III). CP: Gründer Leif Ove Finnerud.
9) *University of Oslo, Department of Informatics*. They run a student course (IN2000) with team-based app development using modern methods, techniques and tools for software engineering. The student groups will interact with the project and its users, creating mutual benefits. CP: Associate Professor Yngve Lindsjørn.
10) *NTNU, Department of Mathematical Sciences.* Supervision of our PhD-student and cooperation on mathematical models. CP: Professor Jo Eidsvik.

<u>University collaboration (UiO and NTNU)</u>

The project will engage students in the course IN2000 at the University of Oslo (UiO), in which student teams develop apps tailored to the needs of specific end users, using modern methods, techniques and tools for software engineering. The course is a 20 ECTS bachelor course in the 4th semester with approximately 250 students working in 50 teams. The student teams will be offered lectures, expertise and guidance from the project partners, access to preliminary project data through APIs, and direct contact with potential end-users. This will give the students research-based learning and software development experience close to realistic work scenarios, and the project will gain more insight into the needs of the end users and have access to a new set of prototype apps by the end of each spring semester. The students develop a relatively complex application using data from MET. The collaboration between UiO and MET is important for the success of the course. The students write a comprehensive report documenting the process and the product (the app). An example of a case is to make an app "Weather at sea in a boat," showing weather forecast and Wave height, given a position, speed and direction.

The project PhD-student will be supervised jointly by Prof Eidsvik at Norwegian University of Science and Technology (NTNU) and project researchers H. Holm (SD) and M.L. Sætra (MET). In addition, Eidsvik will cooperate with the consortium on themes such as Bayesian hierarchical models, and what-if scenarios and optimal positioning of sensors.

3. Implementation

3.1 Project manager and project group

<u>Project leader</u>

The project leader (JE Stiansen, IMR) has a broad experience in leading both small and large projects, as well as with public and community service outreach. He also has long experience in developing databases and public science, as well as time series analyses and oceanographical observations.

Project organisation

The project is compact and highly integrative between the three partners and will have a classical project structure with 4 work packages, where all the partners work closely in each WP. A leader group will be formed of the project leader and the WP leaders and will have the (daily) operationally responsibility and progress. All three partners have WP lead responsibility, so that WP1 will be led by MET, WP2 by SINTEF and WP3 by IMR. WP 4 will be lead by the project leader. The stakeholder group will be invited to the annual project assemblies. Video meetings, project SharePoint and mails will be the daily internal communication platforms.

Partner institution descriptions and specific PI competence

The strength of the consortium is that it brings the observational strength of IMR together with the operational modelling of MET and the methodical strength of SD. At the same time there is significant individual competence overlap among the participants, which builds on already established collaborations. We feel confident that this team, along with the institutional infrastructure, is well suited for conducting this project successfully.

SINTEF DIGITAL is a research division in SINTEF with 400 employees and is here represented by the Department of Mathematics and Cybernetics. They have relevant expertise and experience within computational geoscience and engineering, HPC, big data, and artificial intelligence, and have a strong academic standing in the international community. The department has long experience with developing commercial and open-source numerical simulation code.

- PI: Håvard Heitlo Holm; efficient massively-parallel algorithms for simplified ocean models and nonlinear data assimilation.
- PI: Odd Andersen; WP2 leader, simplified methods, algorithms for geophysical applications
- PhD-student: to be hired, development of local forecast algorithms

IMR is a governmental research institute affiliated to the Norwegian Ministry of Trade, Industry and Fisheries with around 1000 employees. IMR is one of the largest research institutes of its kind in Europe and is an international leader in several research areas. IMR has a robust and varied research infrastructure spread over Norway, ranging from multiple research vessels, a data centre, as well as laboratories. Its Norway's principle organisation on marine observations and host the national marine data centre (NMDC). IMR's research results are open to the public and communicated actively via different platforms to reach diverse audiences. The participants in the project have long experience in data handling of large datasets, modelling of ocean circulation, coastal processes and databases.

- PI: Mari Myksvoll, WP3 leader, coast and fjord oceanography, numerical modelling, oceanic transport mechanisms
- PI: Lars Asplin; coast and fjord oceanography, numerical modelling, water flow dynamics
- Technical staff at IMR IT-department and data center; databases, dataflow, data infrastructure

MET Norway has the national responsibility for producing and disseminating forecasts for the ocean and the atmosphere, and run operational ocean circulation, surface wave, sea ice and atmospheric models. MET Norway also develop and maintain contingency models for decision-making support, e.g. for search-and-rescue operations and oil spill mitigation.

- PI: Kai H. Christensen; WP1 leader, oceanography, air-sea interactions, oceanic drift.
- PI: Martin Lilleeng Sætra; accelerated and massively-parallel models for geophysical applications, data assimilation, scientific visualization.
- PI: Ann Kristin Sperrevik; Ocean observing systems, data assimilation, ocean modelling.

Stakeholder group: This group is described in chapter 2.2

3.2 Project organisation and management

Gantt chart, with project activities, milestones and deliverables are found in the project form.

WP1: User observations and two-way data flows (lead MET)

The goal of WP1 is to take care of the logistics in the demonstrators such that the post processing methods can be tested and personalized forecast can be delivered in an efficient manner. Technical solutions for the general public to register IoT devices and provide data will be set up and tested. Investigations into data ownership and provenance on user supplied data will be made.

- Task 1.1 Develop processes for cleaning, quality-assuring and storing the data
- Task 1.2 Examine what is required to ensure that users are in control of their data (GDPR)
- Task 1.3 Transferring data for “two-way” with protocol and GDPR
- Task 1.4 Output data preparation suitable for frontend (portal)
- Deliverable 1.1 Prototype system for enabling the submission of data from selected IoT devices operational(M6)
- Deliverable1.2 Data transformation system that converts data from selected IoT devices into an appropriate format for inclusion in oceanographic models operational (M12)
- Deliverable 1.3 Report on the impact of data ownership and provenance on user supplied data (M24)

WP2: Personalized forecasts (lead SINTEF)

This work package will research efficient generation of personalized forecasts by using different data assimilation techniques on local and/or simplified ocean models, based on the daily operational forecast and provided user observation. The Ph.D. student will be supervised from SINTEF/NTNU, and successful methods will be used for prototypes for forecasting systems tailored for the demonstrators.

- Task 2.1 Implement statistical downscaling methods for temperature forecasting
- Task 2.2. Extend existing simplified ocean model and nonlinear data assimilation technique to take into account two- or more vertical layers, to use as backend for drift trajectories
- Task 2.3 Explore in recent development within machine learning methods for specifications of model error terms and apply them to simplified ocean models.
- Task 2.4 Develop prototype for forecasting system for demonstrator I
- Task 2.5 Develop prototype for forecasting system for demonstrator II
- Task 2.6 Develop prototype for forecasting system for demonstrator III
- Deliverable 2.1: State-of-the-art and strategy for forecasting framework (model and data assimilation method) for each demonstrator (M12)
- Deliverable 2.2: Draft Ph.D. thesis focused on personalized ocean forecasting methods (M45)
- Deliverable 2.3: Technical report on the forecasting methods for each demonstrator (M48)

WP3: Forecast service demonstrators (lead IMR)

This work package encompasses the work related to user involvement and end user platform. The system will be made available as a web page with visualization of results. Furthermore, users will be able to register their own observations through the portal, and order personalized and enhanced forecasts.

- Task 3.1 Implement demonstrator I. Building on results from WP 1 and 2, and coding of the web service module. Conducted in dialog with demonstrator stakeholder
- Task 3.2 Implement demonstrator II. Implement the demonstrator by building on results from WP 1 and 2, coding of the web service module. Conduct this is dialog with demonstrator stakeholder

- Task 3.3 Implement demonstrator II. Implement the demonstrator by building on results from WP 1 and 2, construct the web service module in dialog with demonstrator stakeholder
- Deliverable 3.1: web module demonstrator I operational (M48)
- Deliverable 3.2: web module demonstrator II operational (M48)
- Deliverable 3.3: web module demonstrator III operational (M48)

WP4: Project integration, administration and dissemination (lead IMR)

In this WP we have collected the integrating tasks cross-laying the project, as well as the administration and practicalities of the project. Further, also dissemination and outreach will be coordinated in this WP.

- Task 4.1 Conduct annual general assemblies
- Task 4.2 Arrange student workshops
- Task 4.3 Hold One-to-one meetings with the different members of the user group
- Task 4.4 Conduct outreach and dissemination (se application form)
- Task 4.5 Project administration
- Deliverable 4.1 Data management plan (M4)

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