RESEARCH PLAN

For Approval of Year 1 Budgets

Initial Projects & Cores

January 2013

MEOPAR

NCE RCE
Networks of Centres of Excellence of Canada | Réseaux de centres d'excellence du Canada

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1. Structure of MEOPAR's Research Effort

Over its projected lifetime of 15 years, the MEOPAR Network will likely address the full range of marine hazards, including those associated with meteorological phenomena (e.g. storms, coastal erosion due to wave action), chemical and biological changes in the ocean (e.g. harmful algal blooms, hypoxia), geophysical phenomena (e.g. tsunamis), and those triggered directly by human activities (e.g. oil spills, ship accidents). The major geographical focus for the first five years will be Canada´s east and west coasts, although the Network will conduct exploratory studies in the Arctic in collaboration with other programs (e.g. the ArcticNet NCE). The Network will also work with closely related projects and institutions that address marine hazards in other parts of the world.

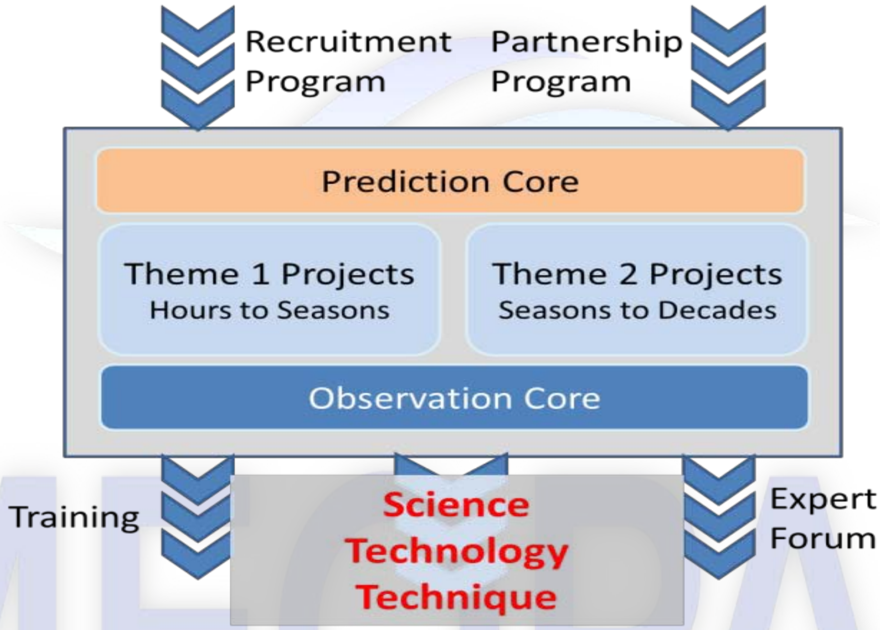


Figure R1. Structure of MEOPAR'S Research Program

MEOPAR's research program is organized around two Themes (see Figure R1) within which research is conducted by Projects. The Themes and their Projects are supported by two "Cores" providing common expertise, tools and technical support. Theme 1 deals with predictions on time scales of hours to a season and focuses on rapid response to marine emergencies. Theme 2 deals with predictions and projections on time scales of seasons to a century. It focuses on quantifying changes in the physical and biogeochemical state of the coupled atmosphere-ocean system on local scales, assessing changes in extremes and risk, and developing scientifically-based adaption strategies.

The themes are based on recognition that (i) the response to specific marine emergencies, and adaptation to a changing climate, occur on different time scales, and (ii) the science and prediction of weather and climate have evolved in a separate fashion over much of the last century. However it is intended that there will be strong interactions between the two themes, some of which will be promoted by joint developments within the two Cores. The latter, comprising a "Prediction Core" and an "Observation Core", will share and optimize use of personnel, software, hardware, and databases across the Network.

Each theme is made up of a number of large, integrated projects that bring together researchers from across the country with expertise in the collection and analysis of observations, modelling and data assimilation, risk analysis and/or vulnerability mapping, etc.. There are two types of project: Initial Projects (two per theme), which commence concurrently with the Network, and Open Call projects which will be funded following open competitions. The Open Call projects will build on the capabilities developed by the Initial Projects and Cores in addressing the Network's strategic vision and objectives. The Open Calls provide opportunities for broader Canadian research community participation in MEOPAR.

In addition to research projects (Initial and Open Call) and the two Cores, MEOPAR will support a number of other activities. These are: 1) a Recruitment Program to encourage involvement of young researchers through provision of additional funds which can be used to accelerate their research programs and promote their integration into projects and the cores; 2) a Partnership Program which will promote involvement of private sector partners, municipalities and NGO's within the Network through provision of matching funds; 3) A Training Program which will support the large number of Highly Qualified Personnel (PhDs and Postdoctoral Researchers) who will be working within the Network's projects; 4) a program of knowledge transfer to policymakers, industry and other sectors. One method of knowledge transfer will be organization of annual Expert Forums. These important aspects of the Network's activities will be the subject of separate plans that will be presented to the Board at the following meeting.

The Network`s research is focused on practical applications but is broad in scope: it bridges weather and climate time scales; it couples the physical, biological and socioeconomic components of the marine environment; it provides a framework for observationalists to work with modellers; it brings together natural and social scientists to solve real life problems faced by multiple groups operating in the marine environment. To realize its strategic outcome and goals, the Network must also address fundamental research questions.

The initial research projects and their associated budgets together with activities and budgets of the two cores, are described in the remainder of this Research Plan. The Research Plan provides detailed spending breakdowns and justifications, together with suggestions for performance metrics, for these components of the Network, which were reviewed at the time of the initial MEOPAR proposal. The plan will be updated and revised on an annual basis, including addition of sections addressing projects initiated via the Open Calls.

2. Project Timing: A 3 + 2 Year Model

MEOPAR's research projects are intended to advance the state of the art and be "transformational". This requires a long-term funding commitment, yet the Network must also have sufficient flexibility to reorient funding in order to respond to emerging possibilities, events, new initiatives, etc., or in case a project does not make progress as planned. Projects and cores are funded according to a "3 + 2" year model which can apply, in principle, to all large-scale projects of MEOPAR (i.e. including both the Initial Projects as well as projects to be funded via "Open Calls"). Under the "3+2" model, projects are proposed with an initial 3 year time-frame, but with the perspective that a follow-on proposal for an additional further 2 years of funding can be submitted and reviewed. A funding decision for the follow-on proposal would be based on the extent to which the milestones and deliverables of the initial 3 year project had been attained, the level of integration and effectiveness demonstrated by the project team, the relevance and prospects of success and stakeholder involvement for the follow-on work, etc.. In essence this decision point acts as both a mid-term review and a "stop-go" point for a project, based on external review as well as review by the Research Management Committee.

This "3+2" year funding perspective does not replace the requirement for the spending plans for projects, and their associated deliverables and milestones to be proposed, reviewed and approved by the Board on a yearly basis in connection with an update of this Research Plan and with the annual performance assessment by the RMC.

A schematic time-plan for MEOPAR project funding over the first funding cycle is shown in Figure R2. Projects supported under the 1st Open Call for proposals, would run until September/October 2016 so that their proposal(s) for follow-on work could contribute to preparation of the Cycle 2 proposal of MEOPAR.

An implication is that funding of a follow-on 2-year period, if approved, would extend beyond the period for which Cycle 1 funds are available (March 31, 2018; see shading on Gannt chart) and would be contingent, in part, on funding of the Cycle 2 proposal. Similarly, funding for the follow-on 2-years of projects funded under a 2nd round of Open Call projects would be fully dependent on the success of the 2nd Phase proposal.

This has disadvantages in terms of project planning security, but conveys a strong incentive on Network PIs to contribute to a high-quality 2nd Cycle proposal. The 3+2 year model implies that a large body of work will be either completed, or at its mid-term point, around the time that the Cycle 2 proposal is being prepared and/or being reviewed.

The Cores should provide a measure of continuity and overall expertise to the widest possible variety of projects. Of importance for the Cores is that they support the projects and allow for broader impact of Network expertise and capabilities (e.g. through bringing together of technical expertise from across Canada). For the Cores, a combination of annual budgets, reviewed for performance, relevance and appropriateness by the RMC and Board, coupled with external review after 3 years, similar to the review of Projects, is suggested. This implies a mid-term review at a time-point when all Initial and Open Call Projects of Phase 1 are either underway or selected (i.e. Fall 2014).

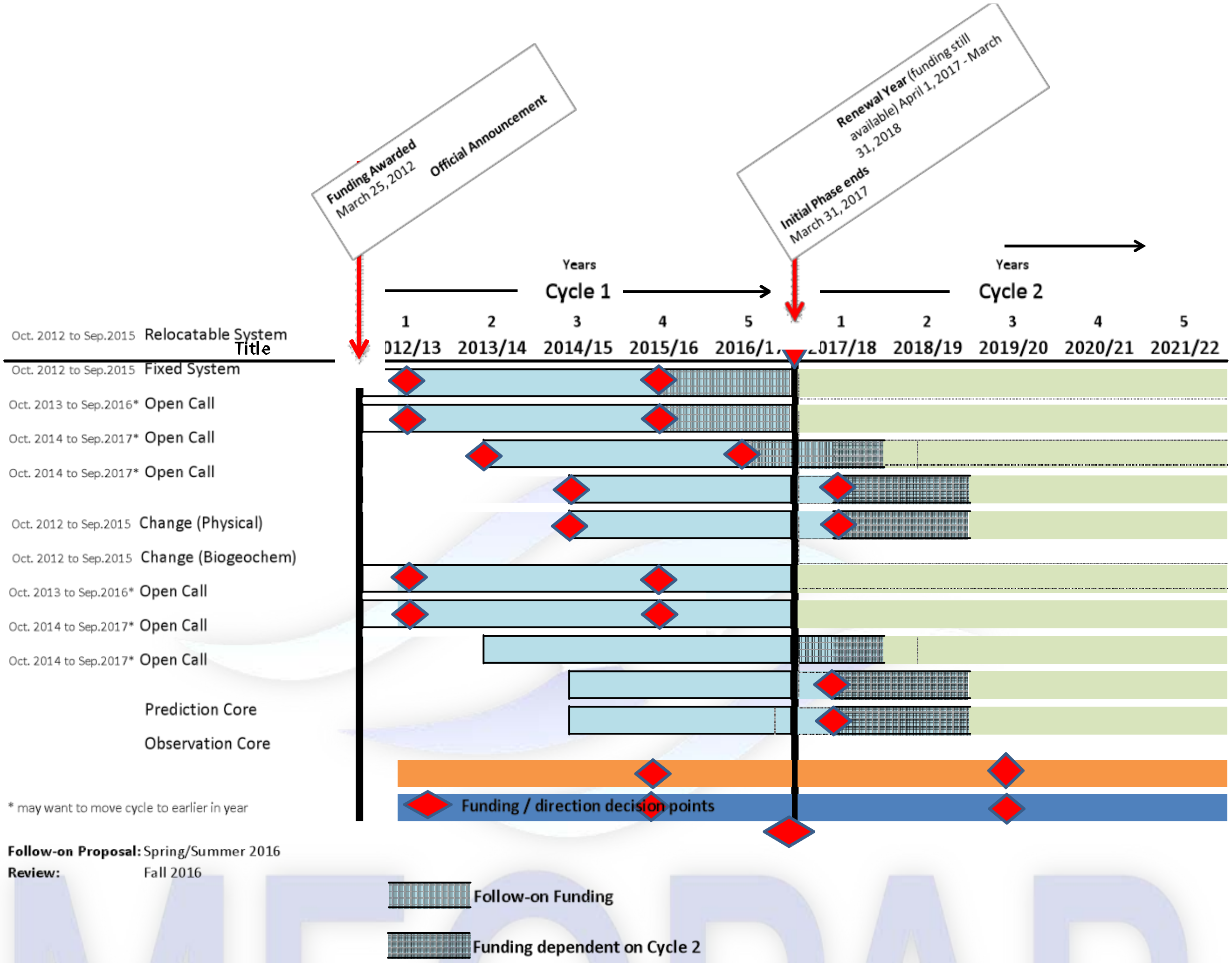


Figure R2: Gantt chart showing the projected timing and duration of MEOPAR projects initiated during the 1st funding cycles.

3. Initial Allocation of NCE Funds

The initial allocation of NCE funds approved by the Board in Year 1 (pending annual review) was as follows: Initial Projects (4 x 3 years); Observation Core (3 years); Prediction Core (3 years); Admin Centre Budget (3 years). The approximate allocation of funds associated with these activities, in relation to the total NCE funds available, is shown in the pie chart.

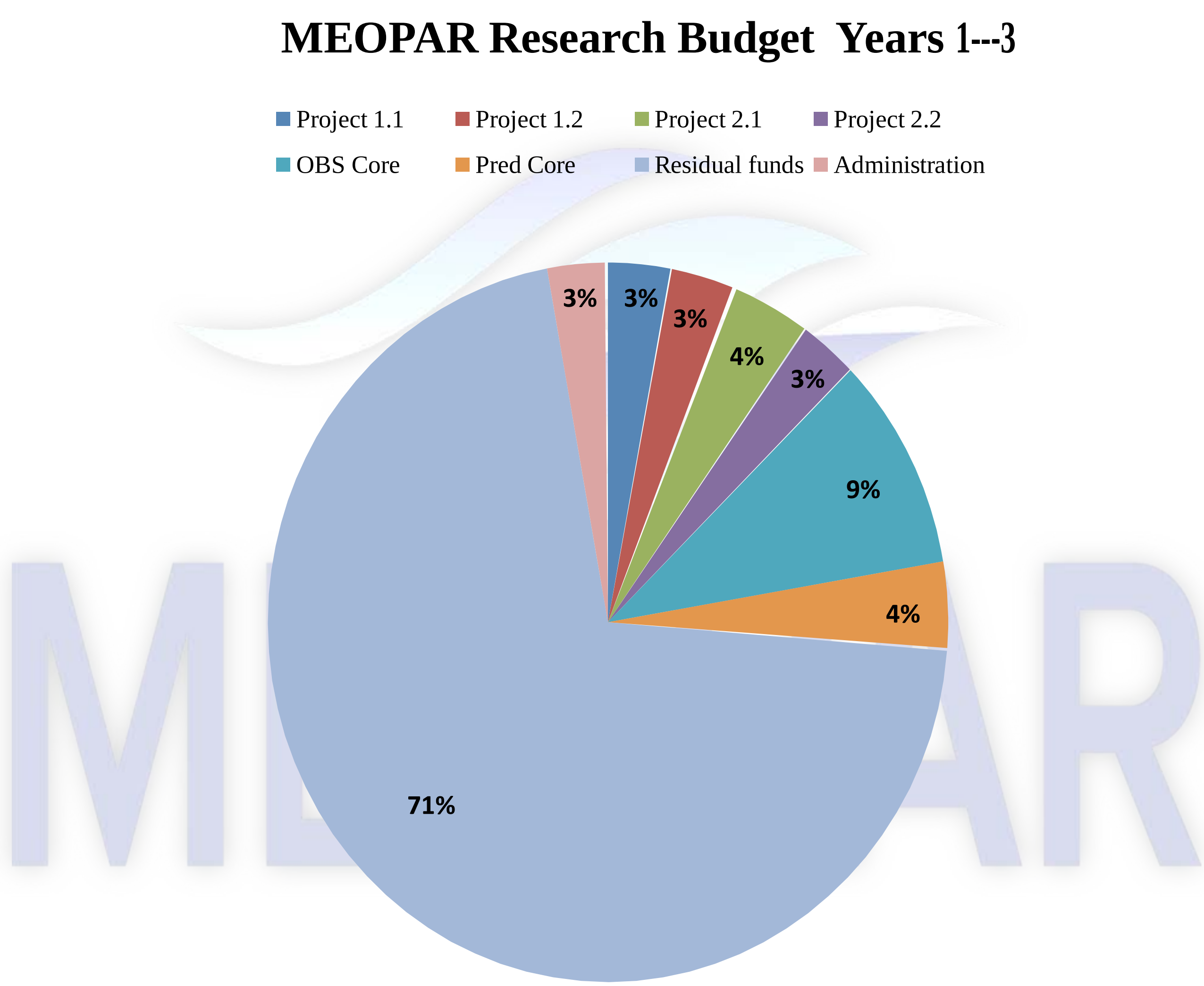


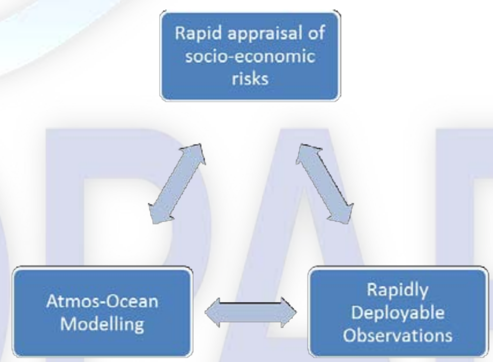
Figure R3: Approximate allocation of funds for the first 3 years of activities as outlined in this version of the Research Plan and in the budget for the Administration Centre. (The total represented by the "pie" is the NCE funding award of $25 million. Residual funds are to support additional "Open Call" projects, the Partnership and Recruitment programs, etc…)

MEOPAR Project 1.1

Theme 1: Initial Project 1.1

A Relocatable Coupled Atmosphere-Ocean Prediction System

Researchers	Multi-Sector	Multi-Discipline
Hal Ritchie	EC, Dalhousie	Global & Regional weather modelling
Ken Lee	DFO, Dalhousie	Oceanography, Offshore oil & gas
Mae Seto	DRDC, Dalhousie	Defence observation systems
Anthony Charles	SMU	Marine socioeconomics & Management
Marlon Lewis	Dalhousie	Ocean biology, Observations & Management
Keith Thompson	Dalhousie	Ocean modelling & Data assimilation
Doug Wallace	Dalhousie	Ocean tracers & Technology
Serge Desjardins	EC	Marine & Coastal meteorology
Fred Whoriskey	Dalhousie	Ocean ecosystem observations
Gilbert Brunet	EC, McGill	Meteorological dynamics & Analysis
Luc Fillion	EC, McGill	Atmospheric data assimilation
Greg Smith	EC	Global & Regional atmosphere-ocean models
Ken Denman	UVic, VENUS	Biogeochemical & Foodweb modelling
Rich Pawlowicz	UBC	Ocean observations & Analysis
Richard Dewey	UVic, VENUS	Physical oceanography, Observations



Problems to be addressed:

- Hazards can be encountered anywhere along Canada's vast coastline and offshore areas including regions undergoing new development and new economic uses.
- These hazards can be encountered anytime
- Canada requires rapidly-deployable forecast system to guide response to marine emergencies.

Desired Outcomes:

- A tested re-locatable coupled atmosphere-wave-ocean data assimilation and forecast system capable of deployment within hours of an emergency.
- New mechanisms for rapid appraisal of socio-economic values and impacts during an emergency.
- Transfer of system to Environment Canada for operational use.

Brief Description of Research Question(s):

A data assimilative coupled atmosphere-wave-ocean forecast system that can be set-up within hours of a marine emergency will be developed in order to provide short-term forecasts (hours to days) of the physical properties of the ocean and atmosphere to help guide the response to the emergency. The system will also include the capacity to track plumes of hazardous materials that can evolve based on the physical conditions. Our research will focus on new capabilities including (i) the ability to relocate the system anywhere in Canadian waters within hours of an emergency, and provide high resolution forecasts of variables such as wind, sea fog, sea level, waves and ocean currents (ii) the assimilation of physical properties of the ocean and atmosphere in order to improve the initial conditions and thus the forecasts (iii) off-line modules for tracking the movement of passive surface, and subsurface plumes, that can take into account the non-conservative properties of spilled materials such as radioactive decay or degrading hydrocarbons and the associated oxygen depletion, and (iv) the explicit integration of knowledge and modelling approaches related to biophysical effects with those dealing with anticipated socioeconomic vulnerabilities, risks and impacts.

Social/Policy Issues to be Addressed (if relevant):

In parallel with the development of the relocatable model, this project will develop new mechanisms for 'rapid appraisal' of socioeconomic values and vulnerabilities relevant to any specific emergency in the marine environment, to enable a real-time and spatially-explicit understanding of potential impacts. The approach will consist of two components: a top-down decision support system based on socioeconomic databases and indicators, and a bottom-up community-focused participatory methodology. Both will draw on values mapping and risk mapping approaches, and will take into account possible impacts on socio-cultural values, on physical infrastructure along coastlines, and on marine-dependent economic sectors. The approach will be developed in the years 2 and 3, then applied to pilot studies in coastal areas of Canada's Atlantic coast, in years 4-5, with iterative refinement of the approach throughout. (This will be closely linked to work in the Strait of Georgia on socioeconomic impacts and indicators of socioeconomic risk, described in project 1.2.)

MEOPAR Partners Involved (so far):

The proposed model and assimilation development and testing builds on existing activities by government partners. Within the inter-departmental CONCEPTS initiative, several government agencies (EC, DFO and DND) are developing an atmosphere-ocean-wave-ice system based on coupling the EC Global Environmental Multiscale (GEM) operational atmospheric forecast system with the shelf version of the French NEMO (Nucleus for European Modelling of the Ocean) forecast system. Under CONCEPTS, this system is being transferred into the operational coupled system for the Gulf of St. Lawrence; it is also being prepared for high resolution operational applications in the Arctic. It will provide an excellent basis for the complementary development by MEOPAR into a relocatable system. As indicated in their letter of support, Environment Canada looks forward to enhancing their current environmental prediction capabilities by incorporating the results of the research and development on the relocatable system, and participating in the associated technology transfer into the suite of operational prediction models run at the Canadian Meteorological Centre.

Suggestions for Additional Partners (e.g. via MEOPAR's Partnership Program):

- Oil and gas industry
- Insurance and re-insurance industry
- Marine transportation
- Public Safety Canada
- Provincial emergency management organizations
- Canadian Coast Guard (Search and Rescue) – Maritimes Division
- Transport Canada

Potential Involvement of Communities, Municipalities or Regional Governments:

- Halifax Regional Municipality
- Greater Vancouver and the Greater Victoria Municipalities.

Timeline and Key Deliverables (first 3 years) (Note: more detail is provided in the accompanying deliverables and milestones documents for the individual investigators)

Year 1:

- Workshop with partners to coordinate planning, user needs, and communication of expected research results. (Ritchie)
- Start development of relocatable capability of GEM-NEMO system (Ritchie)
- Start development of ocean data assimilation scheme for relocatable NEMO ocean model and initially configure for Strait of Georgia (Thompson).
- Start development of relocatable GEM atmospheric model and data assimilation scheme (Fillion)
- Start development of the tracer prediction modules (Lee, Thompson)
- Start developing relocatable tide and storm surge model to provide boundary conditions for relocatable NEMO (Brunet, Ritchie)
- Start preparation and diagnosis of observations and data sets for data assimilation and system validation for Strait of Georgia (Pawlowicz)

Year 2:

- Continue development of relocatable capability of GEM-NEMO system (Ritchie)
- Continue development of ocean data assimilation scheme for relocatable NEMO ocean model configured for Strait of Georgia (Thompson).
- Continue development of relocatable GEM atmospheric model and data assimilation scheme (Fillion)
- Continue development of the tracer prediction modules (Lee, Thompson)
- Continue developing relocatable tide and storm surge model to provide boundary conditions for relocatable NEMO (Brunet, Ritchie)
- Complete preparation and diagnosis of observations and data sets for data assimilation and system validation for Strait of Georgia (Pawlowicz)

- Develop mechanisms for the ‘rapid appraisal’ of socioeconomic values, vulnerabilities and risks associated with an emergency, on a spatially-explicit basis and including local-level community-based approaches. (Charles)
- Project workshop, reporting and planning meeting (Ritchie).

Year 3:

- Complete development of relocatable capability of GEM-NEMO system (Ritchie)
- Complete development of ocean data assimilation scheme for relocatable NEMO ocean model configured for Strait of Georgia, set up for Scotian Shelf (Thompson).
- Complete development of relocatable GEM atmospheric model and data assimilation scheme (Fillion)
- Complete and demonstrate tracer evolution modules (Lee, Thompson)
- Complete developing relocatable tide and storm surge model to provide boundary conditions for relocatable NEMO (Brunet, Ritchie)
- Start development of coupled relocatable GEM-NEMO data assimilation scheme (Fillion, Ritchie, Thompson).
- Initial testing and evaluation of relocatable NEMO model at VENUS site in collaboration with IP1.2 (Pawlowicz).
- Develop mechanisms for the ‘rapid appraisal’ of socioeconomic values, vulnerabilities and risks associated with an emergency, on a spatially-explicit basis and including local-level community-based approaches. (Charles)
- Papers and reports summarizing development and testing of relocatable system to date (All).
- Project workshop, reporting and planning meeting (Ritchie).

Summary of Expected Milestones and Performance Metrics by Year 3

1. Assess the interest and response from first workshop.
2. Successful development of relocatable capability of GEM-NEMO system.
3. Successful development of ocean data assimilation scheme for relocatable NEMO ocean model.
4. Successful initial testing and evaluation of relocatable NEMO model at VENUS site in collaboration with IP1.2.
5. Successful development of relocatable GEM atmospheric model and data assimilation scheme.
6. Successful demonstration of tracer evolution modules.
7. Successful development of relocatable tide and storm surge model to provide boundary conditions for relocatable NEMO.
8. Successful development of mechanisms for the ‘rapid appraisal’ of socioeconomic values, vulnerabilities and risks associated with an emergency, on a spatially-explicit basis and including local-level community-based approaches.
9. Papers in literature and student progress.

Perspectives for Years 4 and 5

Year 4:

- Complete development of coupled relocatable GEM-NEMO data assimilation scheme (Fillion).

- Demonstrate skill of relocatable tide and storm surge model (Brunet, Ritchie)
- Test relocatable system on the Scotian Shelf in collaboration with OTN and the Observation Core, including small scale tracer release experiment (Ritchie, Thompson, Lee, Observation Core).
- Demonstrate mechanisms for the 'rapid appraisal' of socioeconomic values, vulnerabilities and risks associated with an emergency, on a spatially-explicit basis and including local-level community-based approaches (Charles)
- Workshop with partners to evaluate progress and obtain suggestions for improvement (Ritchie).
- Complete testing and real-time implementation of ocean model in the Strait of Georgia (Pawlowicz).

Year 5:

- Development of data/information products for receptor groups and partners (All).
- Publication of results (All).
- Technology transfer of relocatable system to Environment Canada (Ritchie).

Summary of Expected Milestones and Performance Metrics for Years 4 and 5

1. Compare progress (or not) between first and second workshops.
2. Successful trials of relocatable system in specially designed field experiments in collaboration with the Observation Core, e.g. on the Scotian Shelf.
3. Successful application of system Strait of Georgia, based on scientific evaluations and feedback from partners.
4. Successful technology transfer of the relocatable system to Environment Canada.
5. Successful demonstration of mechanisms for the 'rapid appraisal' of socioeconomic values, vulnerabilities and risks associated with an emergency, on a spatially-explicit basis and including local-level community-based approaches.
6. Papers in literature and quality of theses.

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MEOPAR Project 1.2

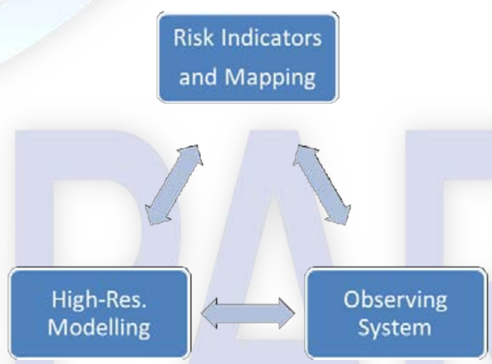
Theme 1: Initial Project 1.2

Building a Network of Fixed Coastal Observing and Forecast Systems

Researchers	Multi-Sector	Multi-Discipline
Ken Denman	UVic, VENUS	Biogeochemical & Foodweb modelling
Stephanie Chang	UBC	Risk & Social/economic impact modelling
Verena Tunnicliffe	UVic, VENUS	Benthic foodwebs, Biodiversity
Richard Dewey	UVic, VENUS	Physical oceanography, Observatories
John Cullen	Dalhousie	Biological observations & Models
Ron Pelot	Dalhousie	Risk assessment, Marine Industry
Jinyu Sheng	Dalhousie	Ocean modelling
William Li	DFO, Dalhousie	Analysis of marine foodwebs
Will Perrie	DFO, Dalhousie	Wave & Storm models
Serge Desjardins	EC	Marine & Coastal Meteorology
Dave Hebert	DFO, Dalhousie	Physical oceanography, Time Series

Problems to be Addressed:

- Economic activity/assets concentrated in specific locations (e.g. harbours, straits, cities) vulnerable to multiple hazards.
- Preparedness for low amplitude/high-frequency and big-amplitude/low-frequency hazards requires observation/prediction systems designed/operated with stakeholders.



Desired Outcomes:

- Observations transformed into useful products and adapted to the needs of multiple users e.g. near-real-time maps of collision risk and forecasts for spill response.
- Indicators of socioeconomic risk derived from predicted quantities e.g. damage to infrastructure, losses to marine-dependent economic sectors.
- Transfer of systems to private sector for commercial purposes.

Brief Description of Research Question(s):

Can state-of-the-art coupled observing systems/forecasting models improve the ability of government and private sectors to respond to existing and emerging marine hazards on timescales of hours to months (e.g., extreme marine weather, storm surges and coastal flooding, extreme waves and currents, movement of marine pollutants, and the occurrence of oxygen depleted waters) in geographically fixed locations of high importance and known marine environmental risks (e.g., major ports or straits)?

This project will build integrated observing and prediction systems for strategically important locations (Halifax Harbour and the southern Strait of Georgia) in order to transform observations into useful products (e.g., forecasts of sea level, waves, currents, biogeochemical properties) for multiple users (e.g., port authorities, municipalities, oil and gas sector). The focus is short term forecasting at potentially very high resolution (tens of meters).

Social/Policy Issues to be Addressed:

Research on spatial mapping of vulnerabilities and the development of socioeconomic risk indicators will be undertaken in order to communicate the information contained in the model forecasts in a manner that is tuned to specific receptor groups (e.g., coastal communities, municipalities, harbour authorities, offshore oil and gas platform operators). Research will also be undertaken on the generation of near real-time spatial maps of the risk of ship collision, and oil spill contamination, that vary through time, depending on the marine environmental conditions forecast by the atmospheric and ocean models.

Main Components of the Research Program

Project 1.2 consists of three components:

Subproject 1.2a: Building a fixed coastal observing and forecast system for Halifax Harbour

Subproject 1.2b: Building a fixed coastal forecast system for the southern Strait of Georgia, incorporating the existing VENUS coastal network

Subproject 1.2c: Analysis of risk and delivery of information to key stakeholders and the public for the two regions

MEOPAR Partners Involved (so far):

The proposed model and assimilation development and testing builds on existing activities by government partners (EC, DFO and DND) under the inter-departmental CONCEPTS initiative. As part of the recently completed DFO Strait of Georgia Ecosystem Research Initiative, a ROMS-based model of the Strait of Georgia and environs has been developed and tested including a planktonic food web module, results which will be available for intercomparison.

Letters of support have been obtained from relevant stakeholders including public and private sectors (see letters from Halifax Port Authority, Halifax Regional Municipality) and also organizations who see potential in the commercialization of this type of integrated observing and prediction systems (see letter of support from Ocean Networks Canada Centre for Engagement and Exploitation).

Suggestions for Additional Partners (e.g. via MEOPAR's Partnership Program):

DRDC, Transport Canada, Canadian Coast Guard
Port Metro Vancouver
BC Ferries: VENUS has instrumented first of 3 BC Ferries
Parks Canada
BC Ministry of Environment
Canadian Parks and Wilderness Society (CPAWS):
All involved in the proposed *Southern Strait of Georgia National Marine Conservation Area* Reserve.

Potential Involvement of Communities, Municipalities or Regional Governments:

Metro Vancouver Regional Authority
Strait of Georgia: Tsawwassen and Musqueam First Nations
Vancouver Harbour/Burrard Inlet: Squamish and Tsleil-Waututh (Burrard Band) First Nations (if the Project expands into Burrard Inlet)

Timeline and Key Deliverables (Years 1-3)

Year 1:

- Reports on workshops (East and West coasts) with partners to coordinate planning, user needs, and communication of expected research results (Sheng, Denman, Chang).
- Catalogue of information sources on Halifax Harbour risks (Pelot).

Year 2:

- A state-of-the-art coastal ocean circulation model for Halifax Harbour based on DalCoast (Sheng).
- A state-of-the-art coastal wave circulation model for Halifax Harbour based on SWAN wave model (Perrie).
- Integrate VENUS observations from cabled sites, ferries, gliders, high frequency radar, into a database for assimilation into NEMO fixed model (Denman, Pawlowicz, in collaboration with the Observation Core).
- Test runs with NEMO model in the Strait of Georgia (Denman).
- Baseline GIS database of coastal uses in the Strait of Georgia (Chang).
- GIS layers of processed shipping traffic in Halifax Harbour (Pelot).

Year 3:

- Real-time coastal ocean forecast system for Halifax Harbour (Sheng).
- Real-time coastal ocean wave forecast system for Halifax Harbour (Perrie).

- Together with Prediction Core, evaluate analyses and predictions from the initial analysis and modelling system, and make results available to partners on a trial basis (Sheng, Perrie, Thompson).
- Assessment of the benefit of assimilation in terms of forecast skill (Sheng).
- High-resolution unstructured grid wave-forecast system for Halifax Harbour. Assessment and validation of the system (Perrie).
- Complete installation and testing of NEMO fixed forecasting model in the Strait of Georgia with assimilation of physical observations from VENUS (Denman).
- Pilot-tested version of selected socioeconomic risk indicators for Strait of Georgia region (Chang).
- Report on non-commercial traffic in Halifax Harbour, and web-mapping service to share results with selected users (Pelot).

Summary of Expected Milestones and Performance Metrics by Year 3

Installation of the fixed systems will be phased for two reasons. First, the CONCEPTS project is largely centred on the East Coast, so the experience with the NEMO ocean model is considerable as is the progress towards coupling with the EC GEM forecasting model that will provide wind forcing. On the West Coast, the only coastal model for the Strait of Georgia uses the ROMS architecture, and no efforts have yet been made to couple a coastal ocean model with a high resolution atmospheric wind forecasting model such as that developed by EC for the 2010 Olympics. CCCMA has been testing the NEMO model for only a few months, but at the global scale. It is thus expected that there will be considerable 'tech transfer' of model expertise and architecture from the Halifax Harbour group to the Strait of Georgia group. Thus for a given year, the expected Milestones and Deliverables will be more mature for the Halifax Harbour installation.

1. Assess the interest and response to the Year 1 workshops with partners and stakeholders.
2. Together with the Prediction Core, evaluation of analyses and predictions from the initial modelling system, and make results available to partners on a trial basis, in collaboration with NIs of Initial Project 1.2 and Prediction Core (Sheng, Perrie, Thompson).
3. Assessment of the benefit of assimilation in terms of forecast skill, and comparison of results with those from existing GEM-NEMO forecasts systems at coarser scale (Sheng).
4. Refine unstructured wave forecast system so as to provide high-resolution predictive ability at key important locations and areas of Halifax Harbour (Perrie).
5. Tested version of NEMO model for the Strait of Georgia, evaluated against VENUS data sets (Denman).
6. Reports from the HQP workshops on trainees' level of satisfaction with their experience in Project 1.2.
7. Publication of results as measured against projected Key Deliverables above.

Perspectives for Years 4 and 5

Year 4:

- Assessment of the benefit of assimilation in terms of forecast skill, and comparison of results with those from existing GEM-NEMO forecasts systems at coarser scale (Sheng, Perrie).
- Publication of development, implementation and testing of data-assimilating version of NEMO in the Strait of Georgia (Denman, Thompson).
- Application of socioeconomic risk indicators to Strait of Georgia and Halifax Harbour cases (Chang).
- Report on the methods and results of the compound risk layer modelling (Pelot).

Year 5:

- Publication of GEM-NEMO results and intercomparison with initial system, and generation of maps of the risk of ship collision taking into account forecast ocean conditions (Sheng, Perrie, Thompson).
- Demonstrate assimilation of selected biogeochemical variables into Strait of Georgia NEMO forecast system (Denman, Thompson).
- Coastal disaster scenarios: Incorporate indicators of socioeconomic risk for users, e.g., damage to physical infrastructure along coastlines, losses to marine-dependent economic sectors (Chang, Denman, Tunnicliffe).
- Final report risk modelling process and maps of risk characterization for Halifax Harbour (Pelot).
- Use of MEOPAR tools by partner and stakeholder organizations in their planning exercises.
- Success at transition of the real time operation of forecast systems for Halifax Harbour and the Strait of Georgia to a private sector partner.
- Incorporation of MEOPAR-generated systems and tools into the procedures of 'operational agencies' responsible for risk planning, warning and mitigation.
- Commercialization of the GIS system developed for Harbour Risk Assessment.
- Demonstrated ability for NEMO to assimilate selected biogeochemical information adding skill relative to forecasts without assimilation.

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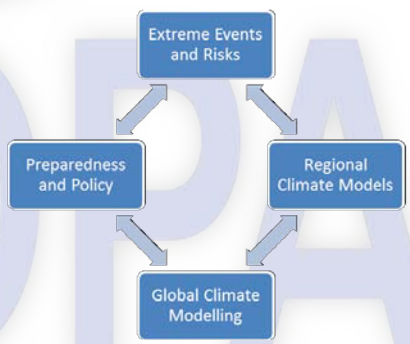
MEOPAR Project 2.1

Theme 2: Initial Project 2.1

Climate Change and Extreme Events in the Marine Environment

Researchers	Multi-Sector	Multi-Discipline
Gregory Flato	EC, UVic	Global & Regional climate modelling
George Boer	EC, UVic	Climate modeling & Analysis
William Merryfield	EC, UVic	Seasonal/Decadal climate prediction
Adam Monahan	UVic	Climate analysis & Statistics
Francis Zwiers	PCIC, UVic	Climate analysis, Extreme event statistics
V 'Slava' Kharin	EC	Climate analysis, Extreme event statistics
Rene Laprise	UQAM	Regional climate modelling
Gordon McBean	UWO	Climate impacts & Risk assessment
Daniel Caya	Ouranos,	Regional climate modelling
Laxshmi Sushama	UQAM	Regional climate modelling
Barbara Neis	Memorial	Risk assessment, Social/Coastal impacts
Ron Pelot	Dalhousie	Risk assessment, Marine industry
Jinyu Sheng	Dalhousie	Ocean modelling
Youyu Lu	DFO,	Ocean modeling & Data assimilation

Problems to be Addressed:



- Risks associated with coastal and marine activities are directly connected to occurrence of extreme events
- The frequency and magnitude of extreme events are expected to change as climate changes
- These changes must be quantified and the uncertainty of projections assessed for planning / risk assessment
- The projections can depend strongly on model resolution and other factors.

Desired Outcomes:

- Projections of extreme wind, storm surges, waves, etc. over the next century.
- Assessment of significance of downscaling using regional climate models for accuracy of projections.
- Improved knowledge mobilization to guide preparedness of communities and industries.
- Improved ability of Government, private sector and coastal communities to prepare for and adapt to altered risk associated with climate change.

Brief Description of Research Question(s):

This project will address questions related to quantification of emerging risks associated with changes in the physical properties of the marine atmosphere and ocean. It will make use of a range of models, from global coupled climate simulation and prediction systems, to high-resolution regional models. It will also make use of various statistical methods to quantitatively evaluate model performance (and hence the reliability of the future predictions and projections they make) as well as to estimate past and future changes in the likelihood and intensity of extreme events, and how they intersect with changes in the mean to increase the risks. Specific risk-related issues to be addressed include those related to the fishing industry and coastal communities and their exposure to extreme weather events.

Social/Policy Issues to be Addressed (if relevant):

Climate change impact assessments, adaptation planning, and policy development rely on scientifically-based quantitative information about the future climate and the future of societies, both people and infrastructure. In order to reduce risks, exposure and vulnerability need to be addressed through societal actions. This research will improve our understanding of the strengths and weaknesses of existing models, and our ability to provide quantitative information about future climate extremes which are so important to the impacts that will arise from a changing climate. It is also necessary to project changes in exposure of people and asset, particularly those in coastal communities and those involved in marine-related industries.

MEOPAR Partners Involved (so far):

Environment Canada (Canadian Centre for Climate Modelling and Analysis)
Centre ESCER, Université du Québec à Montréal
University of Western Ontario
Coastal Cities at Risk (CCaR): Building Adaptive Capacity for Managing Climate Change in Coastal Megacities
Institute for Catastrophic Loss Reduction
University of Victoria
Memorial University of Newfoundland[1]
Dalhousie University
Pacific Climate Impacts Consortium
Ouranos Consortium
Department of Fisheries and Oceans (Bedford Institute of Oceanography)

Suggestions for Additional Partners (e.g. via MEOPAR's Partnership Program):

- Public Safety Canada
- Provincial emergency management organizations, such as New Brunswick
- Canadian Coast Guard (Search and Rescue) – Maritimes Division
- Transport Canada

Potential Involvement of Communities, Municipalities or Regional Governments:

- Greater Vancouver and the Greater Victoria Municipalities. Through CCaR we have already had meetings with Greater Vancouver and would continue these and extend to Victoria.
- Halifax, Kentville and other Atlantic Canada communities

Timeline and Key Deliverables (first 3 years)

Year 1:

- Atlantic Canada consultation workshop and report (McBean)
- Initial analysis of multi-season forecast skill for marine variables, making use of existing retrospective forecast output (Merryfield/Boer/Flato)
- Initial development of Atlantic coast wave model based on WAVEWATCHIII (Sheng)

Year 2:

- British Columbia consultation workshop and report (McBean)
- Initial wave model runs and their validation using wave observations (Sheng)
- Initial implementation of bias correction strategy for use in subsequent downscaling (Laprise)
- Development of a coupled atmosphere/upper-ocean single column model underway (Monahan)
- Initial model configuration and test forecasts with seasonal prediction system extended to include ocean biogeochemistry (Merryfield/Flato)
- Review of literature on impacts of weather extremes on fishing vessel accidents (Neis)
- Evaluation of observed and simulated coastal storm trends and variability (Zwiers)

Year 3:

- Second Atlantic Canada consultation workshop and report (McBean)
- Initial version of spatial model of risks to fishing vessels (Pelot)
- Analysis of physical controls on extreme winds and nonlinear statistical downscaling method developed (Monahan)
- Bias-corrected regional downscaling completed at ~15km resolution, covering period 1950 – 2100, driven by CanESM2 global model and a single GHG scenario. (Laprise)
- Analysis of 20-year historical simulation of Atlantic wave conditions using wave model and bias-corrected regional downscaling model output (Sheng).
- Assessment of prospects for seasonal to interannual prediction of storm-related extreme events in the coastal environment (Zwiers).

Summary of Expected Milestones and Performance Metrics by Year 3

- New regional downscaling results for a single RCP scenario, for the period 1950-2100, driven by bias-corrected CanESM2 global model output.
- Physically-based analysis of extreme winds and the processes involved in wind extremes.
- Model-based estimate of extreme wave statistics off Canada's east coast.

- Demonstrated capability for dynamical downscaling of multi-season climate predictions.
- Initial configuration of coupled climate prediction system with ocean biogeochemistry capability.
- Literature review of risk assessment methodologies and reports on BC and Atlantic consultation workshops.
- Initial assessment of risks to fishing fleets and draft fleet preparedness plan based on MEOPAR modelling results.
- Datasets on coastal storm activity; papers and 'extension' material summarizing trends and variability in coastal storm activity.

Contact information for the project leader:

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MEOPAR Project 2.2

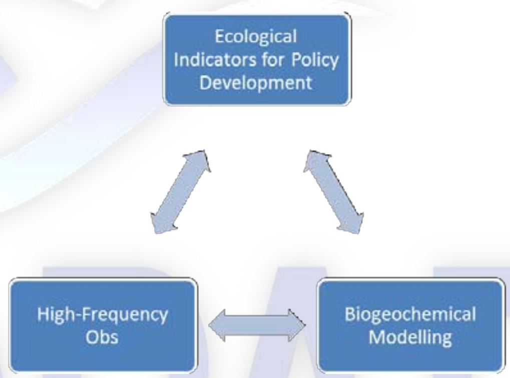
Theme 1: Initial Project 2.2

Biogeochemical Projections Under a Changing Climate

Researchers	Multi-Sector	Multi-Discipline
Katja Fennel	Dalhousie	Regional biogeochemical models/Data assimilation
James Christian	DFO, UVic	Global biogeochemical models
Dan Henstra	U. Waterloo	Political science, Climate adaptation policy
Eric Galbraith	McGill	Global biogeochemical models
John Loder	DFO	Physical oceanography, Regional data
Helmuth Thomas	Dalhousie	Carbon chemistry observations
David VanderZwaag	Dalhousie	Marine environmental law
Kumiko Azetsu-	DFO	Carbon chemistry observations
Catherine Johnson	DFO	Marine biology, Metabolism

Problems to be addressed:

- Globally, oceans are warming up, becoming more acidic and losing oxygen.
- The global "biogeochemical changes will have local ecosystem impacts.



Desired Outcomes:

- Regional biogeochemical model projections that allow assessments of risks at scales that matter over time scales of decades to a century.
- Assessment of use of indicators within ocean law and policy frameworks designed to protect the marine environment.
- New science-based indicators for ecosystem health that capture impact of changing ocean biogeochemical environment and are useful for ecosystem based management.

Brief Description of Research Question(s):

Initial Project 2.2 will quantify and project changes in the marine biogeochemical environment including the occurrence of phenomena such as hypoxia and acidification and their potential impact on living marine resources on timescales of seasons to centuries. Ocean acidification, a necessary and well-documented consequence of rising atmospheric CO2 levels, will likely have severe impacts on many calcareous species (including commercially valuable bivalves and crustaceans) and may fundamentally alter the structure and functioning of marine ecosystems. The effect of acidification is compounded by a global de-oxygenation of the ocean as a consequence of decreased ventilation of deeper waters due to surface warming. These trends in DIC and oxygen will impose physiological constraints on marine animals by reducing the amount of energy available to them and will threaten economically valuable and endangered species directly and indirectly through changes in primary productivity at the base of the marine food chain and changes in ecosystem structure and function. The potential impacts of these changes in marine environmental conditions will have to be considered in the management of marine resources.

The overarching objectives of this project are to provide 1) a quantitative assessment of the risks to marine ecosystem services in eastern Canadian coastal waters that emerge in the face of drastic changes in the ocean biogeochemical environment, specifically its productivity, acidity and oxygen levels, within the next decades to century, and 2) to link these findings with developments in ocean law and policy through an assessment of governance frameworks aimed at protecting the marine environment.

This will be accomplished by regional downscaling of coarse-resolution global biogeochemical models to a high-resolution regional model for the eastern seaboard of Canada with consideration of the relevant biogeochemical processes. Some enhancements to Canada's global earth system model and a comparative analysis of available global biogeochemical projections will be undertaken in support of this downscaling activity. The skill of the downscaled regional model will be assessed by comparisons with targeted observations supported by this project and supplemented by observations from other sources. The tested model will then be used to project selected time slices in the future (e.g. 2050-2060, 2090-2100) from which products for policy and decision makers will be derived (e.g., changes in suitable habitat for commercially important and endangered species). The implications for marine policy will be assessed, with particular focus on indicators used in ecosystem-based management practices.

Social/Policy Issues to be Addressed (if relevant):

We consider the policy issues that will be addressed in the project to be research questions and described them already in the previous section.

MEOPAR Partners Involved (so far):

The Department of Fisheries and Oceans is an important partner evidenced by the fact that four DFO scientists (James Christian, John Loder, Kumiko Atzesu-Scott and Catherine Johnson) are collaborators on this project. Collaborations will range from collection of in situ observations and access to DFO ships to sharing of expertise in model development.

The Gulf Aquarium and Marine Station (GAMS) in Cheticamp, NS is an NGO aiming to connect various stakeholders concerned with the use of living marine resources (e.g. local fishermen). GAMS has provided us with a letter of support for the proposal. One obvious avenue of collaboration is through participation in the Annual Fishermen's Forum in Cheticamp. There likely are ways in which a more substantial collaboration and partnership can be built, but those have not yet been explored/discussed.

Suggestions for Additional Partners (e.g. via MEOPAR's Partnership Program):

We have an interest in pursuing collaborations with Brazilian colleagues under the Bilateral Brazil-Canada Cooperation Agreement that just came in effect. Katja Fennel took part in the first workshop on cooperation under this new agreement, which took place in Rio de Janeiro in May 2012. Initial contacts were made during this workshop. Katja Fennel is in discussion with Moacyr Araujo, head of the Institute for Risk Reduction at the Universidade Federal de Pernambuco in Recife. The next Brazil-Canada workshop is tentatively planned for October 2012 in Halifax.

David VanderZwaag is proposing a partnership between MEOPAR and the Australian Canadian Ocean Research Network (ACORN) in order to pursue comparative research on the uses and challenges in generating Climate Change–related science and insuring its appropriate influence in law and policy responses. ACORN (established in 1993) is a network of leading Australian and Canadian law and policy researchers and has a proven track record of comparative research having published to major books and a third volume in preparation. One of ACORNs major objectives is to bring together natural and social scientists to collaborate in ocean governance research.

Potential Involvement of Communities, Municipalities or Regional Governments:

We would like to involve the Nova Scotia fishing community (GAMS is an identified partner and will help with this effort). We will engage the branches of regional government concerned with management of living marine resources (especially those that set policy). David VanderZwaag in his role at the Marine Environmental Institute will take the lead in this effort.

Timeline and Key Deliverables (first 3 years)

Year 1

- Workshop with NIs, collaborators and stakeholders for research planning, coordination and communication of expected products and user needs (all)
- Data set of existing carbon measurements for the study region compiled and available for model implementation and validation (Helmuth Thomas, Kumiko Atzetsu-Scott)
- Collection of inorganic carbon data underway (Helmuth Thomas)
- AZMP data set available for model validation (Catherine Johnson)
- Initial model simulations for present day conditions with inorganic carbon and oxygen available and initial model validation (Katja Fennel)
- Acquisition of global coupled climate-biogeochemical projections initiated (Eric Galbraith)
- Review of global and regional indicators of marine ecosystem health with a focus on the inclusion of biochemical indicators completed and comprehensive bibliography available (David VanderZwaag).

Year 2

- Workshop with NIs, collaborators and stakeholders for research planning, coordination and communication of expected products and user needs (all)
- Additional year of data collection completed and updated carbon data set for Station 2 and AZMP surveys available for modeling (Helmuth Thomas, Kumiko Atzetsu-Scott)
- Updated AZMP data set available for model validation (Catherine Johnson)
- Improved model simulations for present day conditions available and validated (Katja Fennel)
- First set of global coupled climate-biogeochemical projections available (Eric Galbraith, James Christian)
- Initial regional simulations for future time slices available (Katja Fennel, Eric Galbraith, James Christian)
- Review completed of how global agreements and arrangements apply to and are responding to the threats of ocean acidification and hypoxia and summary report available (Vanderzwaag)

Year 3

- Workshop with NIs, collaborators and stakeholders for research planning, coordination and communication of expected products and user needs (all)
- Additional year of data collection completed, updated carbon data set for Station 2 and AZMP surveys available for modeling and publication or report and conference presentation (Helmuth Thomas)
- Updated AZMP data set available for model validation (Catherine Johnson)
- Acquisition of coupled climate-biogeochemical model output from global models completed and documented in report or journal article and presented at an appropriate conference (Eric Galbraith)
- Data set of enhanced output of CanESM2 (incl. oxygen) available (James Christian)
- Model simulations for present day conditions presented in form of publication or report and conference presentation (Katja Fennel)
- Improved regional simulations for future time slices available (Katja Fennel, Eric Galbraith, James Christian)
- Comparison of how regional sea arrangements (fisheries and environmental) are addressing the challenges of climate change, both scientifically and from a governance perspective, completed and prepared for publication (David VanderZwaag)

Summary of Expected Milestones and Performance Metrics by Year 3

- Reports, data sets, scientific publications and presentations at workshops and conferences as measure of scientific output overall
- Publications and presentations by HQP as a measure of training
- Demonstrated interactions with different stakeholders as a measure of societal impact
- Stakeholders (incl. fishing communities, local and regional decision makers and managers, academia) better aware and informed about anticipated long-term changes to the coastal marine environment

- Stakeholders (incl. academia, managers, communities, local and regional decision makers) better aware of legal framework (incl. its shortcomings) for ecosystem-based management

Perspectives for Years 4 and 5

- Inorganic carbon measurements at Station 2 and during AZMP surveys will continue. Continued support for measurements is crucial if we are to distinguish anthropogenic trends from natural variability.
- Ensembles of projected time slices with coastal ecosystem model will be completed and analyzed. Results will be made available in form of data sets and publications.
- Evaluation of adequacy of governance arrangements and measures to address human pressures and global change will be completed and available as report or publication.
- Model products based on indicators will be generated. Translating scientific model output into more accessible products is crucial as these are needed by decision makers and useful to all stakeholders. A completed suite of finalized model products will be made available to all stakeholders.

Contact information for the project leader:

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Tel. 902 494 4526
Katja.fennel@dal.ca

MEOPAR Prediction Core

Researchers	Multi-Sector	Multi-Discipline
Rene Laprise	UQAM	Downscaling from large to small spatial scales
Jinyu Sheng	Dalhousie	Coastal observing, Prediction
Youyu Lu	DFO, Dalhousie	Support for the NEMO model
Ron Pelot	Dalhousie	Risk assessment, Visualization models
Jim Christian	UVic	Global biogeochemical modelling
Stephanie Chang	UBC	Socioeconomic indicators

Brief Description of Issues for the Prediction Core:

The Prediction Core will respond to the needs of multiple projects including provision of services related to coupled and ocean modelling, downscaling, biogeochemical modelling and assimilation, assessing and visualizing risk, definition of socioeconomic indicators, and transfer of model technologies to operations. The Core's activities will lead to the efficient use of resources, and the transfer of knowledge among Network Investigators and HQP. The Prediction Core will interact strongly with Theme 1 and 2 projects and the Observation Core, and thereby strengthen Network integration. The Core will also be expanded to provide services to the Open Calls as their common needs become more clearly defined.

Core staff will also provide a direct means of information sharing across projects and allow some flexibility in assigning human resources to project researchers as and when needed. The models of interest to the Prediction Core include coupled atmosphere-ocean and biogeochemical models. It is important however to note that the models of interest to the Prediction Core go beyond models of just the atmosphere and ocean. The Core will develop new ways of assessing and visualizing risk, and also defining and evaluating socioeconomic risk indicators. No single common model code (e.g., atmosphere-ocean model) has been prescribed for the Network and so the codes developed by the Core will be modular and generic, allowing for flexibility, utility and interoperability. The Prediction Core will maintain a central code repository, with standardized documentation, to maximize access to the major codes developed by the projects and the Cores. The main areas in which the Prediction Core will be active are listed below.

The Prediction Core will provide models that translate particular outputs of the atmosphere- ocean and ocean biogeochemical models in Themes 1 and 2 into socioeconomic impacts. This service will facilitate the use of Theme 1 and 2 models for planning and decision-making by end- user groups such as coastal infrastructure organizations or emergency managers. These tasks will build on existing loss models where available (e.g., Okuyama and Chang, eds., 2004; Vickery et al., 2006) and draw on data from recent coastal disasters, both in Canada and abroad. Such models are relatively well established for hazards such as storms, but nascent for other hazards such as oil spills and sea-level rise. Key research challenges will include developing models for the latter. One Research Associate will work under supervision of Professor Stephanie Chang on socioeconomic indicators, primarily in support of IP1.2 (Strait of Georgia) and also, in later years, to both Initial Projects under Theme 2.

Social/Policy issues to be addressed (if relevant):

The work on assessing and visualizing risk and on socioeconomic indicators are both of direct relevance to social and policy issues. By translating outputs of the atmosphere-ocean and ocean biogeochemical models in Themes 1 and 2 into socioeconomic impacts, the Prediction Core will facilitate the use of MEOPAR models by end-user groups such as coastal infrastructure organizations or emergency managers; for example, in planning for and responding to emergencies as well as making long-term investment decisions for risk reduction.

Main components of the research programme:

- **Activity A: Support for the NEMO model:** The ocean model that will be used most widely by the Network is the NEMO (Nucleus for European Modelling of the Ocean) forecast system (Madec 2008; Brasseur et al., 2005; Dombrowsky et al., 2009). It will be used extensively in the downscaling activities of IP2.1, and the real-time applications of the Theme 1 projects. The Prediction Core will provide technical support for model configuration, initialization and running, error diagnostics, one and two way coupling, specification of surface fluxes, and transition of codes to operations. One Postdoctoral Fellow will provide assistance with these tasks with primary responsibility to IP2.1 but also IP1.1 and IP1.2 and will work under the supervision of Dr. Youyu Lu.

- **Activity B: Downscaling from Large to Small Spatial Scales:** An important activity in Themes 1 and 2 is the coupled modeling at large scales and downscaling the results to relatively small spatial scales. The regional modelling activities of the Theme 2 Initial Projects, and the relocatable coupled atmosphere-ocean models of Theme 1 (IP1.1), all require coupled modelling and downscaling capabilities. One Research Associate will work, under the primary supervision of Prof. Rene Laprise, on coupled prediction, downscaling and the transfer of technology to operations. The primary responsibility will be to IP2.1 but supporting, and sharing ideas and codes, with IP2.2 and IP1.1.

- **Activity C: Biogeochemical Modelling Development:** Biogeochemical models provide time-evolving boundary conditions for regional models that can assess the impacts of ocean acidification and deoxygenation. The field of biogeochemical modeling is undergoing very rapid development both in terms of process parameterization and a movement towards assimilation of biogeochemical observations. A Research Associate position will be assigned for 2.5 years to work under the supervision of Jim Christian on modifications and enhancements of the CCCMa Earth System Model including incorporation of additional biogeochemical tracers into the model and evaluation of the NEMO modeling system as an alternative ocean model. The RA will work closely with Project 2.2. Future allocation of this position for the final 2 years of Phase 1 will be determined based on a survey of the needs of the Initial and Open Call projects for biogeochemical model development.

- **Activity D: Assessing and Visualizing Risk:** This activity will develop ways of assessing and visualizing changes in the marine environment and the associated risks. The risk maps derive from spatial probability maps and the associated impact distribution. Of particular interest will be the quantification of uncertainty in predictions and projections. One Research Associate will work under the supervision of Prof. Ron Pelot on this topic, primarily responding to IP1.2 and IP2.1. For IP1.2, detailed spatial maps of the ocean conditions related to the movements of vessels for navigation risk, and to spills for drift modelling, will be devised. For IP2.1, the MEOPAR outputs will be mapped to the receptors of the extreme events, be they coastal communities or fishing fleets. The multi-criteria impact maps are essential for assessing and communicating the risks associated with the conditions and predictions generated through the Network‟s observations and models.

- **Activity E: Socioeconomic Indicators:** One of the strengths of MEOPAR is that it covers both physical and socioeconomic impacts. An important issue for the socioeconomic applications is the definition of suitable risk indicators, taking into account the vulnerabilities associated with a specific application. Examples of socioeconomic risk may include damage to physical infrastructure along coastlines (e.g., port facilities, oil and gas storage tanks) as well as losses to marine-dependent economic sectors (e.g., fisheries, aquaculture, tourism, shipping). The development of socioeconomic indicators is non trivial and requires research into the dependence of vulnerability on predicted changes in the marine environment.

MEOPAR partners involved (so far):

Suggestions for Additional partners (e.g. via MEOPAR's Partnership Program):

Potential Involvement of Communities, Municipalities or Regional Governments:

Emergency Management British Columbia (EMBC)
City of Vancouver and potentially other municipalities in MetroVancouver

Work with communities and governments will also be conducted and organized primarily through the associated projects.

Milestones (Years 1-3)

Year 1:

- Create a regional ocean and sea-ice model that can be used as a "reference" for NEMO model users in various themes of MEOPAR; initial development of documentation and software for model configuration, initialization, running, error diagnostics, etc. (Youyu)
- Runs with NEMO using the native PISCES ocean ecosystem model; offline tests of revised ocean ecosystem and biogeochemistry modules. (Christian)
- Scoping out of the required and available data inputs for risk assessment will be conducted. The type, timing, volume and format of available data will be ascertained from all of the MEOPAR research groups, but in particular from those working on Initial

Projects 1.2 and 2.1, where risk assessments are part of the formal work plan. The preliminary plan of what the final risk assessment and visualization product will look like will be developed in consultation with government and industry partners and other relevant stakeholders. (Pelot)

- Workshop with regional partners to coordinate planning, identify user needs and forms of communicating expected research results (see Project 1.2b); (b) Compilation of resource catalog of information sources on coastal risks, focusing on socioeconomic impacts of rapid-onset hazards; (c) Literature review on socioeconomic impacts of oil spills: empirical analyses and models; (d) Decision on scope of socioeconomic risk indicators (hazards and impacts) to be developed in future years (Chang)

Year 2:

- Develop a basin-scale NEMO for coupled regional climate downscaling (IP2.1); provide support to other components (IP1.1 and IP1.2) of MEOPAR on development of high-resolution regional NEMO models. Refine model documentation and softwar. (Youyu)
- Porting of the GEM-NEMO code from EC computer in Dorval to CLUMEQ-II computer used by ESCER/UQAM completed. (Laprise)
- Replacement of PISCES with new ocean ecosystem model; commence coupling NEMO to the CCCMa atmosphere model. (Christian)
- Based on formats of data that have been, or will be, gathered though MEOPAR measurements, particularly those for projects 1.2 and 2.1 (or in the absence of actual data for certain variables, using proxies for this development phase), begin the development of a risk model that is based on multi-criteria spatial assessments. In particular Halifax Harbour risks will be characterized by vulnerable areas and shipping traffic metrics, to reflect the susceptible elements. For Project 2.1, fishing fleet risks will be considered according to location and type of activity. (Pelot)
- Expanded literature review to other hazard(s) selected: empirical analyses and models; (b) Mapping of coastal uses relevant to hazards and impacts selected (Strait of Georgia); (c) Other data collection. (Chang)

Year 3:

- Assess the performance of basin-scale NEMO model in hindcating of ocean and sea-ice variability, both in stand-lone mode and in coupled CRCM mode (IP2.1) at various time scales, through comparison with ocean and sea-ice observations; provide support to performance assessment of regional NEMO models in other components (IP1.1 and IP1.2) of MEOPAR. (Youyu)
- Regional climate simulation of CRCM5 coupled with NEMO, driven by atmospheric reanalyses and prescribed ocean transports, over a coastal region of Canada, completed. (Laprise)
- Coupled model runs with NEMO and revised ocean ecosystem and biogeochemistry modules. (Christian)
- A rudimentary multi-criteria spatial risk model will be developed. It will take input from MEOPAR models of extreme events, and translate the information into probability and severity maps, which can then be overlaid with the vulnerability maps created in year two, to assess the overall risk in an area. In particular, this will be done for Halifax

Harbour, and for some east coast fishing fleets identified in years 1 and 2 as good candidates for risk prevention studies. (Pelot)

- (a) Development of suite of socioeconomic risk indicators; (b) Semi-structured interviews with experts (e.g., port managers) to gather data on vulnerabilities and input on risk communication; (c) Other data collection; (c) Pilot-testing of selected socioeconomic risk indicators (Strait of Georgia). (Chang)

Key deliverables (Years 1-3)

Year 1:

- A "reference" regional ocean and sea-ice model based on NEMO; initial documentation and software for model configuration, initialization, running, error diagnostics, etc. (Youyu)
- A report will be produced on what the risk assessment and visualization analysis and product will comprise, based on the assessed needs of the end-users in conjunction with the information generated through MEOPAR studies. In particular, this will include a catalogue of information sources on Halifax Harbour risks for project 1.2, and feedback from affected fishing communities for project 2.1 (Pelot)
- Contribution to Project 1.2b workshop report; (b) Literature review on socioeconomic impacts of oil spills. (Chang)

Year 2:

- A basin-scale NEMO model for couple regional climate downscaling of IP2.1; high-resolution regional models in collaboration with researchers of IP1.1 and IP1.2. (Youyu)
- GEM-NEMO code running on CLUMEQ-II computer. (Laprise)
- Ocean biogeochemistry model results to be downscaled for regional applications, for climatological and historical cases. (Christian)
- Data layers will be produced in a Geographic Information System (GIS) that contain information for some of the vulnerable areas and activities that can be affected by extreme weather events. The data layers are subject to expansion and revision as the MEOPAR project progress and additional information become available. (Pelot)
- (a) Baseline GIS database of coastal uses in Strait of Georgia region; (b) Literature review on socioeconomic impacts of selected other coastal hazard(s). (Chang)

Year 3:

- Performance assessment of basin and regional NEMO models in collaboration with researchers of IP2.1, IP1.1 and IP1.2. (Youyu)
- Software for running regional climate simulation of CRCM5 coupled with NEMO, and archival of simulated results. (Laprise)
- Ocean biogeochemistry model results to be downscaled for regional applications, for potential future climate states. (Christian)
- A prototype spatial multi-criteria risk model will be completed, that shows how the risk varies over time and space in the designated study areas, as a function of the threats determined through MEOPAR measurements and models, and the vulnerable areas and activities mapped out in years 1 and 2. A report on the model development will be produced, as well as journal articles. (Pelot)

- (a) Suite of socioeconomic risk indicators; (b) Pilot-tested version of selected socioeconomic risk indicators for Strait of Georgia region. (Chang)

Contact information for the project leaders:

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MEOPAR Observation Core

Core Leads: Brad deYoung, John Cullen

Network Investigators: M. Babin, R. Bachmayer, T. Charles, K. Denman, D. Lane, K. Lee, M. Lewis, W. Li, R. Pawlowicz, M. Seto, V. Tunnicliffe, D. Wallace, D. Hebert

Brief description of issues for Core:

The Observations Core will support three principal classes of activity with respect to observations and observing capacity within MEOPAR:

- Targeted development of new observational techniques and platforms of broad relevance to MEOPAR's projects and objectives.
- Augmentation of existing measurement systems and provision of technical support and quality control services for observing techniques used widely across multiple MEOPAR projects.
- Network support services, including assembly, and support of access to the observational data sets, both environmental (e.g. remote sensing) and socio-economic required by MEOPAR projects.

Social / Policy issues to be addressed (if relevant):

A specific part of the data management activities is focused on rapid assembly of socio-economic data related to marine emergencies.

MEOPAR partners Involved (so far):

Exxon Mobil Canada Ltd.
Irving Shipbuilding Inc.
OEA Technologies
Port of Halifax
Halifax Regional Municipality
Canadian Coast Guard, DFO, DRDC, Environment Canada
Ocean Networks Canada
Ocean Tracking Network

Suggestions for Additional Partners (e.g. via MEOPAR's Partnership Program):

Atlantic Towing Inc.
Encana
International Submarine Engineering Ltd.
Rolls-Royce Naval Marine Canada, Inc.
Teledyne Webb Research

Potential Involvement of Communities, Municipalities or Regional Governments:

Observations Core involvement with communities and governments is conducted primarily via the associated projects (e.g. project 1.2).

Observation core activities

Years 1-3:

1. Tethered Float Development (Brad deYoung and Ralf Bachmayer, Memorial) which will, initially, be linked with the Scotian Shelf observations for testing, calibration and early deployments. This is a new technical development in direct support of Initial Project 1.1
2. Dorado Autonomous Vehicle Development (D. Wallace, M. Seto and K. Lee, Dalhousie) This is a new technical development which is also in direct support of Initial Project 1.1
3. Scotian Shelf Observations (J. Cullen, D. Wallace, Dalhousie) will support a variety of observational systems collecting data in direct support of Initial Projects 1.1, 1.2 and 2.2. This includes installation and operation of new measurement systems on the Atlantic Condor supply vessel as well as routine sampling at time-series sites.
4. CODAR-Halifax (Coastal Ocean Dynamics Application Radar) as a prospective component of Scotian Shelf observing system (Jinyu Sheng, Keith Thompson, Dalhousie and Brad deYoung, Memorial). This is in support of Projects 1.1, 1.2 and 2.2
5. Strait of Georgia (VENUS) Observations (Verena Tunnicliffe, Univ. Victoria). This activity will support provision of additional data streams from ships-of-opportunity (ferries) and gliders in support of Projects 1.1 and 1.2. The data streams will extend the capability of the VENUS observing system in the Strait of Georgia.
6. Network Support Services (Brad deYoung, Memorial; John Cullen, Dalhousie and Marcel Babin, Universite Laval). This activity supplies Network-wide support related to data management, supply and quality control as well as network-wide access to remote-sensing products for MEOPAR projects.

1) Tethered Float Development (B. deYoung and R. Bachmayer, MUN, PIs):

The goal of this project is to develop and test a tethered profiler for deployment at the site of emergencies (e.g. in support of the relocatable model). We will work with the APEX profiler of Teledyne Webb Research. APEX is an autonomous drifting profiler used to measure subsurface currents and make profile measurements. The challenge is to develop a method to tether the profiler to a fixed mooring allowing the profiler to move vertically but to be constrained from drifting away from the site of interest. The profiler will be allowed to surface to transmit data, and can be programmed for different vertical profiling missions.

2) Dorado autonomous vehicle development (D. Wallace, Dalhousie, PI with Mae Seto and Kenneth Lee).

This technical development, in support of model validation for Project 1.1, is to modify an existing, unique Canadian Autonomous Surface Vehicle, DORADO, from its present role for mine countermeasures, into a platform for conducting rapid surveys of the marine environment.

Key characteristics of DORADO include: speed (up to 16 knots) allowing for rapid surveying of mesoscale ocean features; power (diesel-powered engine generates sufficient power for complex instrumentation); stability (allowing for continuous sampling of near-surface waters and atmosphere at high speed); tow capability (for profiling of subsurface waters). The vehicle will have the capability to make unattended measurements of deliberately-introduced chemical tracers (e.g. SF_5CF_3) that can be used in dispersion experiments as well as fluorescence-based measurements of oil. The proposed work represents an collaboration with Defence Research and Development Canada (see DRDC letter of support) and offers a context for cooperation with a number of companies including the manufacturer, ISE Ltd, Port Coquitlam, BC).

3) Scotian Shelf Observations (J. Cullen, D. Wallace, Dalhousie, PI): Activities within this category include hands-on and information technology support for sampling over the Scotian Shelf on Atlantic Condor, sampling and instrument testbed activities in Halifax Harbour and approaches, liaison with OTN glider data streams and other observation systems on the Scotian Shelf, as well as technical advice for development of glider operations capabilities elsewhere in MEOPAR. These observations will contribute to Projects 1.2, 2.2 and, potentially, a field test within Project 1.1 in year 4.

Specifically, the Scotian Shelf observation activities will include:

- Technical support for installation and sustained observations of the Scotian Shelf on the Atlantic Condor offshore supply vessel, specially related to in-situ optical and chemical sensor systems, instrument installations, and data management, including implementation of quality control procedures. The MEOPAR personnel will also coordinate routine sample analysis from this platform. The Atlantic Condor is an offshore supply vessel which is owned by Atlantic Towing Ltd. and operated under long-term charter to Encana Inc. for servicing of their Deep Panuke gas platform near Sable Island. The vessel offers a remarkable opportunity to collect a broad variety of data concerning physical (e.g. ADCP), chemical, biological, geological and atmospheric aspects of the continental shelf offshore of Halifax. Its projected long-term operation (up to 10 years) and high-frequency of sailing (1-2 transits per week) offers unique opportunities for data collection, especially relevant to MEOPAR projects 1.2 and 2.2. Installation of measurement systems is presently under discussion with Encana, Atlantic Towing and other parties. The proposed measurement program on Atlantic Condor represents an ambitious partnership between academic, government (DFO, NRCan, EC), and industry partners which if successful could be extended to other Canadian supply vessel operations (e.g. off Newfoundland).
- Development and validation of a tethered buoyancy-driven profiling float system with an interdisciplinary sensor package (CTD, oxygen, nitrate, optics), ultimately to be used for deployment in the open ocean and in connection with use of MEOPAR's relocatable model. Tethering technology will be developed by MUN; Dalhousie will focus on sensor systems. A simple tethering design will be tested initially in Halifax Harbour. Observations from the profiling system will be validated in Bedford Basin weekly in collaboration with BIO's Bedford Basin Plankton Monitoring Programme (Bill Li).

4) CODAR Halifax (Coastal Ocean Dynamics Application Radar): for measurement of currents and waves in the Halifax Approaches. This is a prospective, important component of a Scotian Shelf observing system and of wide use to MEOPAR projects and a variety of user communities outside academia. The necessary equipment exits (upgrades may be needed), but the required systems have yet to be installed and an operation plan developed. Year 1 will be devoted to planning, guided by establishment of a CODAR Team. Subject to development of a plan and approval by the Board, the resulting installation and operations plan will be implemented in years 2 -5. A workshop will be convened in year 1 with MEOPAR partners (e.g., DRDC, DFO, Halifax Port Authority), MEOPAR researchers, and a representative of the VENUS CODAR team. The CODAR Team will present a work plan and budget for installation and operation of the CODAR system, for discussion in the RMC prior to approval by the Board. Funding of CODAR during years 2 - 5 will be contingent on approval of this plan and budget.

5) Strait of Georgia Observations (VENUS) (Verena Tunnicliffe, Univ. Victoria): The primary use of these funds will be to support extensions to the installed VENUS observing system: specifically partial support for establishment of measurements from Volunteer Observing Ships (BC Ferries) and introduction of glider operations using the two Venus gliders. These additions have similarities with plans for the Scotian Shelf (e.g. Atlantic Condor, above) and MEOPAR allows for exchange of technical knowledge and experience between East and West Coasts. VENUS does not have the funds to support additional these operational costs and the data will be used in support of Projects 1.1 and 1.2.

6) Network support services: This category includes a range of common activities applicable across projects.

a) *Sensor calibration (John Cullen, Dalhousie Univ.)* – A large number of sensor systems will be added in conjunction with the proposed expansion of data collection described above. The Observation Core will take responsibility for ensuring that the new sensors added via MEOPAR (see above) are calibrated to assure data quality control. This proposed centralization of sensor calibration activities offers opportunities for negotiation of reduced prices (for periodic factory calibrations) and for initiating dialogue concerning common data quality standards and, even, equipment sharing. The estimated costs for Y1-Y3 are for instrumentation to be used in support of the Scotian Shelf and Strait of Georgia observations. A refined estimate of instrumentation requirements and sensor calibration costs will be developed through consultation and negotiation across the Network in Y1.

c) *Data management (Douglas Wallace, Dalhousie University and Tony Charles, St. Mary's Univ.)* – MEOPAR data management support is for two RA positions and a PDF. One RA will work on socio-economic data for the Network under the supervision of Tony Charles. The RA will develop mechanisms for „rapid appraisal‟ of socioeconomic values, vulnerabilities and risks associated with emergencies, on a spatially-explicit basis and including local-level, community-based approaches. While of immediate relevance to Project 1.1, the approaches have relevance to activities ongoing in other projects (especially 2.1, Neis / Pelot) and in the Prediction Core (Chang). Exact deployment of the remaining personnel will not commence before Year 2 given that prior consultation within and outside the Network is required. A workshop will be held in early 2013 to determine how best to approach data collection and integration within MEOPAR, as well as consider the links of MEOPAR to related data management activities elsewhere in Canada and internationally. On the basis of this workshop, a plan will be developed for Years 2-3 and beyond.

d) *Remote Sensing (Marcel Babin, Universite Laval)* – During year 1, the remote sensing data service will be implemented at Laval University in close association with the CERC on "Remote sensing of Canada's new Arctic frontier", and based on the hiring of one RA supported by MEOPAR. The primary focus of this service will be on products derived from ocean color. Some other RS products (e.g. SST) can be provided, but at the expense of ocean color services. Both standard products from NASA and ESA, and newly developed products will be provided to MEOPAR users on grids and at frequency specified by them. The CERC will provide the additional resources needed to develop new algorithms and products (contributions from two CERC RAs). To establish links with the users of remote sensing data within MEOPAR, and to collect user requirements for remote sensing products, we intend to convene a dedicated workshop during Y1. It will bring together remote sensing, in situ observation, and modelling teams. This activity will be supervised by Marcel Babin as described in the original proposal.

e) *Travel* – These funds will be used to support Workshop support and other Observation Core activities including technician travel, special course offerings that are of broad Network relevance, the workshop for data management discussion (see above). In Y1 or Y2 we will also organize and support a national workshop on use and support of ocean gliders. The latter workshop will be hosted by Memorial University and Oceans Advance in St. John's.

Timeline and key deliverables (first 3 Years):

Year 1

- Tethered Float: Hiring of personnel; design of tether
- Dorado: Hiring of personnel, initial prototype construction of mini-GC, initial technical plan for DORADO installations
- Scotian Shelf Obs.: workshop on Scotian Shelf Obs. and integration of Atlantic Condor data; Workshop report; technical planning of Atlantic Condor installations; Technical description; installation of flow-through-tank
- CODAR: planning workshop; workshop report including proposal for Y2, 3 support to RMC / Board.
- Strait of Georgia (VENUS) Obs.: test data from BC Ferries available; CODAR data available; technical description available via MEOPAR Obs. Core web-page; data handling procedures discussed with Scotian Shelf counterparts.
- Network Support Services: data management workshop; workshop report; initiate sensor calibrations; written plan and procedures for sensor calibrations. Hire remote RA (Laval): workshop on remote sensing needs of projects; workshop report; web portal for remote sensing products (linked to MEOPAR data portal); provide travel support for Obs. Core workshops and travel.

Year 2

- Tethered Float: float purchase; sensor installation; lab. testing; report on design and test of float.
- DORADO: GC testing in lab: sensor system installed on DORADO; initial report on mini-GC; trials at dockside or in Bedford Basin; report on trial.
- Scotian Shelf Obs.: testing of tethered float in Bedford Basin; data handling plan for Atlantic Condor measurements; install data/comms system on Atlantic Condor; purchase and install Moving Vessel Profiler on Atlantic Condor; design and initiate regular sampling and analysis program linking Bedford Basin, Halifax Approaches and Atlantic Condor; Regular reports on sampling activities on web-page; develop and test web-based portal for data access; prototype data portal.
- CODAR: tender of contract (subject to RMC and Board approval of budget); installation of system; initial data provided to MEOPAR data portal; annual report on activities.
- Strait of Georgia (VENUS) Obs: First glider mission; mission report; glider data management discussed with other Canadian glider groups (at glider workshop); workshop report; data to projects and linked via MEOPAR data portal.
- Network Support Services: hire data management personnel (2 RAs); 2nd data management workshop; workshop report; data management plan; sensor calibrations; creation of MEOPAR data access web portal; distribution of remote sensing products to projects; support Obs. Core workshops and travel.

Year 3

- Tethered Float: field testing in Bedford Basin; trial deployment; final report on status; scientific publication
- DORADO: trial in Bedford Basin; GC installation in DORADO and testing in vehicle; planning of tracer release experiment; publication about mini-GC; report on testing and trials; planning document re: tracer release
- Scotian Shelf Obs.: document measurement program procedures and protocols; report on procedures; continuation of sampling program and initiation of MVP measurements on Atlantic Condor; regular reports of measurement activities on web-page; initiation of measurements using MVP; public launch of web-based data portal.
- CODAR: maintain data collection; data served via MEOPAR data portal; annual report on activities.
- Strait of Georgia (VENUS) Obs.: continue glider missions; continue BC Ferry data collection; data to projects and linked via MEOPAR data portal
- Network Support Services: annual data management workshop; workshop report; sensor calibrations; MEOPAR data and metadata publicly available via web portal; distribute remote sensing data to projects; support for Obs. Core workshops and travel.

Summary of Expected Milestones and Performance Metrics by Year 3

- Development of new, unique technologies for rapid environmental assessment in emergencies
- Network-wide, national approach to management of MEOPAR-related data and provision of data products, including web-portal for data
- Major enhancement of observation systems for the Strait of Georgia and Scotian Shelf

- Novel cooperation with private sector on long-term data collection (BC Ferries, Atlantic Towing, Encana, etc).
- Establishment of a national approach to sensor calibration
- Easy accessibility of data on the web for MEOPAR projects
- Technical reports and enhanced web-based visibility of oceanographic data.
- Data uptake by projects

Perspectives for Years 4 and 5

We expect that Years 4 and 5 will see use of the new technological approaches and data systems in major, high-profile experiments linked to the existing, initial projects and/or new projects initiated via Open Calls.

We expect growing interest in the newly-developed technologies for rapid environmental assessment, including commercialization and partnership possibilities

We expect MEOPAR Obs.Core to continue to contribute to a national effort towards establishment of operational ocean and marine atmosphere measurement systems.

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