2008 Progress Report

Global Ocean-Atmosphere Prediction and Predictability (GOAPP) Network

Submitted to:

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

350 Sparks Street, Suite 901
Ottawa ON K1R 7S8

Submitted by:

Global Ocean-Atmosphere Prediction and
Predictability (GOAPP) Network
Network Manager
Department of Oceanography
Room 5660A LSC
Dalhousie University
1355 Oxford Street
Halifax, NS B3H 4J1

Tel: (902) 494-5035
Fax: (902) 494-2885
Email: swoodbury@dal.ca

Date of Submission: June 24, 2008
Approved by the GOAPP Board of Directors June 24, 2008

2008 Progress Report

Global Ocean-Atmosphere Prediction and Predictability (GOAPP) Network

This second progress report of the Global Ocean-Atmosphere Prediction and Predictability (GOAPP) Network covers the period from July 1, 2007 to June 30, 2008.

In accordance with instructions from the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS), this report answers a series of questions posed under the general headings of Progress, Impact, Level of Support, Dissemination, Training and Other. As requested by CFCAS, the report is a non-scientific description of progress.

For each GOAPP project we have presented the specific objectives and milestones for year 2 and the progress achieved to date. Please note that two projects (I.2.3 and II.1.1) were removed from the network at contract award and two new projects (I.1.6 and II.3.4) were added this year due to the reallocation of funds after the departure of R. Greatbatch.

We have also included in this report appendices containing Acronyms and Abbreviations (Appendix A), lists of personnel involved in the Network (Co-Investigators, Researchers, Scientific Steering Committee Members, Board of Directors, and Collaborators, Appendix B), the 2008 Annual GOAPP Workshop Agenda and CMOS Presentations (Appendix C) and the GOAPP Science Day Agenda (Appendix D).

1 PROGRESS (1 JULY, 2007 TO 30 JUNE, 2008)

1.1 DESCRIBE PROGRESS TOWARDS MEETING THE PROJECT OBJECTIVES. HOW ARE THE ORIGINAL MILESTONES BEING MET? LIST THE KEY OBJECTIVES AND RESULTS ACHIEVED TO DATE AS WELL AS ANY RELEVANT APPLICATION(S) OF THE RESULTS.

The Network has been functioning now for 21 months and the overall progress has been excellent. All of the research personnel (graduate students, post doctoral fellows, and research associates) are in place and the Network Secretariat continues to provide excellent service. The Scientific Steering Committee has undergone the required annual rotation of membership and has functioned well in terms of providing scientific guidance to the Principal Investigators and also reflecting the opinions of the wide range of co-investigators from across Canada with different scientific backgrounds.

During this reporting year one of the co-investigators (R. Greatbatch) left Canada, and the network, to take a new faculty position in Germany. This provided the opportunity to fund two new projects that have added significantly to the scope and applications of the network's research. Aaron Berg will assess the impact of improved land surface initial conditions on the accuracy of seasonal predictions, with a particular focus on the prediction of drought. In addition

to expanding the scope and relevance of GOAPP's research this new project also links our network to CFCAS' Drought Research Initiative (DRI) network. The other new project is led by Jinyu Sheng and focuses on the downscaling of predictions of the deep ocean to continental shelves where many of the most pressing marine environmental problems and resource management issues occur. This applied project is of particular interest to the Department of Fisheries and Oceans.

One of the highlights of this reporting period was the GOAPP annual workshop held in Kelowna on 25 May 2008. The goals of the meeting were to review progress, introduce the new projects, identify problems and opportunities for new research, encourage collaboration, discuss information management and review network structure. (Appendix C gives the agenda and a list of participants.) The meeting was well attended and successful. We are particularly pleased to note the attendance of Dr R. Stewart, the scientific leader of the DRI network, for most of the day. The reason for holding the annual workshop in Kelowna at this time was to link the workshop to the Annual Congress of the Canadian Meteorological and Oceanographic Society (CMOS). GOAPP researchers chaired three session blocks during CMOS that primarily covered the research of GOAPP researchers. (In total 19 talks and 3 posters were presented by GOAPP researchers. See Appendix C.) This provided excellent exposure of GOAPP research to the Canadian scientific community, and also the opportunity for GOAPP researchers to inform each other of their recent progress.

Another important event during this reporting period was the GOAPP Science Day held at the Cambridge Suites Hotel on February 28, 2008 in Halifax. This was an opportunity to brief the GOAPP Board of Directors, and a wider audience, on the science being tackled by the network researchers. Close to 35 people from GOAPP Themes I and II, the Board of Directors (including Dr E. Dombrowsky who travelled from France), Environment Canada, Fisheries and Oceans Canada and the Department of National Defence attended the all day meeting. The agenda can be found at Appendix D. The Science Day focused primarily on research undertaken by Theme I. It was suggested that the next Science Day be held on the west coast, coincident with a face-to-face meeting of the Board of Directors, and the scientific focus will be Theme II research.

Individual projects have generally made excellent progress with some of them exceeding their year 2 milestones. The remainder of this section describes the progress achieved by individual projects, grouped by Theme. The milestones for year 2 for each project are given in italics. It will become clear when reading these descriptions that many of the co-investigators and their research personnel are working on more than one project and thus the research is both collaborative and integrated.

Theme I: Days to Seasons

This subsection describes progress made during year 2 under Theme I. Almost all of the ocean modelling effort in Theme I is based on the NEMO ocean model code in order to facilitate collaboration and also accelerate its development and application. All of the atmospheric research and modelling in Theme I is based on the GEM (Global Environmental Multiscale) model. Thus, the researchers in Theme I have made an effort to limit the number of models and

make best use of their limited resources. The only exception is the ongoing use of the Parallel Ocean Program (POP) model for some ocean data assimilation development work. These developments are presently being implemented and tested in the NEMO model. The network as a whole has maintained some diversity of ocean and atmospheric models because the Theme II researchers are using a different coupled modelling system (based on the CCCma model code).

Theme I investigators initiated a Discussion Group at Dalhousie University in order to encourage collaboration. Local investigators and visitors have been invited to talk about their work in an informal and constructive environment. All presentations are made available to all GOAPP investigators on the GOAPP webpage and comments and discussion are invited. This informal meeting has made significant contributions to the cohesiveness of Theme I.

There have also been exchange visits by investigators within Theme I, and also between Theme I and II, that have been very useful for technology and scientific exchange, particularly with regard to recent ocean modelling and data assimilation developments and also large scale atmosphere-ocean coupling. (Details are provided below.) These visits have been useful and will be more actively encouraged through the establishment of a fund that can be used to support future exchanges.

Sub-Theme I.1 Ocean Modelling and Data Assimilation

Project I.1.1 Suppression of Bias and Drift in Ocean Model Components
Co-Investigators: D. Wright, K. Thompson

The specific objectives of this project are (i) Implement and test the spectral nudging technique in the basin-scale and global ocean models developed in Theme I, (ii) Make the developments available to project I.1.4 on ocean hindcasting and forecasting using basin-scale and global models, and also to sub-themes I.2 and II.3.1 focused on coupled global atmosphere-ocean modelling and data assimilation.

Schedule and Milestones:

The milestones for year 2 are (i) Evaluate the need for and feasibility of developing extensions to include spectral nudging in the equatorial region (within a few degrees of the equator), and (ii) Complete model developments and testing, and make the modified code available to other projects and sub-themes. This project will be largely completed in the second year, but evaluation of modifications suggested by other elements of the proposal will continue at a reduced level of effort.

Prior to July 2007, the basic spectral nudging code had been implemented in NEMO and verified to give results similar to those obtained previously with the POP model. Since July 2007, we have:

i) Tested the Bell et al. pressure correction method for reducing bias in ocean models. Unfortunately, the method improved results in the equatorial region, but actually

degraded results for the Gulf Stream separation region. We decided to investigate other possibilities to increase our control of the development of large scale mean bias.

ii) We implemented code that is specifically designed to remove bias from the time-mean state. This can easily be achieved by very slowly adjusting the effective temperature or salinity that the model temperature or salinity is nudged towards. This works well but introduced other problems as discussed below.

iii) When the time-mean bias is eliminated as above, this very strongly imposes any errors in the observational estimates of hydrographic conditions on the model and results in spurious results; this problem has been dealt with in the past by spatially smoothing the nudges. With the stronger bias reduction, we found that stronger spatial smoothing is required which is not a major problem except that it can be computationally expensive. To deal with this issue, we have developed a recursive spatial filter that allows us to apply strong spatial smoothing to the mean nudges without requiring a significant increase in computer resources. Use of the recursive spatial filtering approach required a perfectly conservative spatial filter; this has been developed and shown to work well.

We believe that with the above developments and the use of improved surface forcing fields (see I.1.4) that any problems with the development of model bias will be controllable. The spectral nudging routines have been included in the version of NEMO made available on the GOAPP website and GOAPP investigators have been given assistance with using the code when requested. Dr. Wright will visit CCCma this summer to work with Dr. Merryfield to include spectral nudging in the ocean model used by Theme II investigators and to discuss technical issues associated with its usage.

Project I.1.2 Statistics of Observed Variability for Model Testing and Improvement Co-Investigators: K. Thompson, M. Foreman and E. Demirov

The overall goal of the project is to use statistics describing the mean state of the ocean and its variability to test the realism of eddy resolving models of the North Atlantic and North Pacific, and improve the models and their forcing functions. The observed statistics are (i) the mean sea surface topography based altimeter data and the most accurate regional geoids available, (ii) variance and skewness of sea level measured by altimeters, and (iii) mean, variance and skewness of surface drifter velocities.

The milestones for year 2 are (i) Collate mean and variability statistics for the North Pacific. Undertake numerical experiments to test sensitivity to variations in a small number of controls for the North Pacific (using ¼ degree OPA configuration). Continue development and testing of the tangent linear/adjoint models and use them to gauge sensitivity of the spectral nudges in the North Atlantic to changes in a "large number of controls" including surface forcing, lateral boundary conditions and bathymetry.

A study was undertaken to assess the accuracy of a new mean sea surface topography (MSST) of the North Atlantic. The MSST is based on 12 years of altimeter data referenced with respect to a

new regional geoid based on a blend of GRACE (Gravity Recovery and Climate Experiment) and terrestrial gravity measurements. The new MSST was first compared to the mean surface topography of an eddy permitting model of the North Atlantic published recently by Thompson, Wright, Lu and Demirov (2006). Geostrophic currents calculated from the GRACE-based MSST were next compared to mean surface currents estimated from the motion of near-surface drifters corrected for surface Ekman effects. Finally the mean path of the Gulf Stream inferred from the MSST was compared to the line of zero skewness of sea level variability that is taken as a measure of the mean path of unstable, intense ocean currents. Overall the agreement amongst the various estimates of MSST and circulation is excellent. There are, however, some significant differences that can be separately attributed to problems with the MSST and, in some cases, with the ocean model (in particular the ocean climatology to which it was nudged). A manuscript on the subject has been submitted to Journal of Geophysical Research. The title is "The Mean Surface Topography of the North Atlantic: Comparison of Estimates based on Satellite, Terrestrial Gravity and Oceanographic Observations" and the authors are K. Thompson, J. Huang, M. Veronneau, D. Wright and Y. Lu. This work is funded in part by the GEOIDE network through the involvement of K. Thompson and graduate student Simon Higginson.

A similar study was also undertaken of the MSST of the North Pacific. Average summer and winter MSST have been calculated for the Northeast Pacific using climatological temperatures, salinities, winds, and satellite altimetry. The manuscript "Dynamic ocean topography for the Northeast Pacific and its continental shelves" by M. Foreman, W. Crawford, J. Cherniawsky and J. Galbraith is in preparation and should be submitted this summer.

Maps of MSST, and also the standard deviation and skewness of sea level variability, for the North Atlantic were provided to F. Dupont (working with D. Wright) as part of his study of parameter optimization for the North Atlantic NEMO model. (This work relates to the sensitivity of the model to variations in a small number of controls mentioned in the milestones above. It is described in more detail in I.1.4 below.)

The tangent linear (TL) and adjoint codes required for a variational data assimilation system have been derived by hand for a simplified version of the NEMO model. This code will be used to assess the sensitivity of the ocean model to variations in a large number of controls as mentioned in the milestones above. The tangent linear and adjoint models will also be used to reconstruct inter-annual variability of the North East Pacific Ocean circulation. Preliminary results were presented at the CMOS 2008 meeting about the derivation of TL and adjoint code of one dimensional component of NEMO model. A Green's function method to estimate physical parameters in NEMO has also been formulated and related subroutines will be implemented into NEMO by the end of June 2008.

Eddy permitting runs of the North Pacific using a spectrally nudged version of the NEMO model at ¼ degree resolution are presently underway. Maps of the MSST, standard deviation and skewness of the model's sea level fields are imminent.

Work has continued on the effect of spectral nudging on the energy budget of the North Atlantic. The manuscript "Evaluation of the effects of the model drift in the simulations of the North

Atlantic: Impact on the model energetics" by E. Demirov, K. Thompson and D. Wright is in preparation and should be submitted this summer.

Project I.1.3 Multivariate Assimilation of Altimeter and Argo Data for Ocean Forecasting
Co-Investigators: E. Demirov, K. Thompson and M. Foreman

The specific objectives for this project are (i) Determine means and error covariance structure of the altimeter and Argo data to be assimilated into the global and basin models using 3DVar (ii) Test and compare performance of new assimilation schemes for altimeter and Argo profile data.

The milestones for year 1 are (i) Calculate the background error covariance for the auxiliary variables (ξ_D, ξ_T and ξ_S) using the ¼ degree North Atlantic model developed in project I.1.2. The covariances will be estimated using the new maximum likelihood approach. (ii) Use these covariances to assimilate Argo and altimeter data for the North Atlantic using the new auxiliary variable-based scheme. (iii) Implement the SEEK filter for the North Atlantic (building on the SAM2 code to be provided by Mercator). Year 2: (i) Repeat steps (i), (ii) and (iii) from year 1 for the North Pacific. (ii) Continue assessment and improvement of the auxiliary-based assimilation scheme and SEEK filter applied to the North Atlantic. (iii) Assess the impact of better regional geoids, and other improvement stemming from project I.1.2, on the assimilation of altimeter and Argo data.

Results Achieved to Date:

A new method for data assimilation of satellite and Argo data has been developed by Thompson and Liu. It is a computationally-efficient scheme for assimilating sea level measured by altimeters and vertical profiles of temperature and salinity measured by Argo floats. The scheme is based on a transformation of temperature, salinity and sea level into a set of physically-meaningful variables for which it is easier to specify spatial covariance functions. It also allows for sequential correction of temperature and salinity biases, and online estimation of background error covariance parameters. Two North Atlantic applications, both focused on predicting mesoscale variability using the POP ocean model, have been used to assess the effectiveness of the scheme. In the first application the background is a monthly temperature and salinity climatology and skill is assessed by how well the scheme recovers Argo profiles that were not assimilated. In the second application the backgrounds are forecasts made by an eddy permitting model of the North Atlantic. Skill is assessed by the quality of forecasts with lead times of 1 to 60 days. Both applications show the scheme has useful skill that exceeds 20 days over most of the North Atlantic, and 10 days in the Gulf Stream region. A manuscript has been submitted to Monthly Weather Review on the new data assimilation scheme. The title of the paper is Predicting Mesoscale Variability of the North Atlantic Using a Physically-Motivated Scheme for Assimilating Altimeter and Argo Observations by K. Thompson and Y. Liu.

More recently significant effort has been expended in shifting the data assimilation from the POP ocean model to the NEMO system for the North Atlantic. This has involved (i) preliminary adjustment of the model and rewriting of assimilation codes, (ii) development of I/O tools (including restart capabilities that are independent of the CPU number, allowing restart files to

be conveniently exchanged between different computer platforms), (iii) addition of items to the control file "namelist", in order to output model results and restart files according at different time steps and for different time intervals (iv) diagnosis of the model's behaviour in order to estimate the coefficients to be used in the data assimilation. Initial experiments have been performed with the NEMO assimilation system and compared to free run predictions. Analysis of results is underway. We anticipate that the scheme will be implemented in the North Pacific model (also based on NEMO) next year.

The comparison of the MSST based on the GRACE geoid (see I.1.2) have indicated problems not with the model, or assimilation scheme, but with the temperature and salinity climatology to which the model has been spectrally nudged. It is thought that the problem is the result of aliasing of the interannual and longer period variability of the hydrography. This has resulted in a new research effort to develop epoch-dependent climatologies based on the idea of 'de-eddying' vertical profiles of observed temperature and salinity using altimeter data. This work is being pursued by Simon Higginson, a PhD student under the supervision of Keith Thompson. (The student is not funded by GOAPP but benefits from, and contributes to, its research activities.)

Two other data assimilation systems are under development. The tangent linear (TL) and adjoint codes required for a variational data assimilation system have been derived by hand for a simplified version (one dimensional component) of the NEMO model. (See I.1.2 above for details). A three dimensional version of TL and Adjoint codes will be prepared by the end of March 2009. A Green's function method to estimate physical parameters in NEMO has also been formulated and related subroutines will be implemented into NEMO by the end of June 2008.

A North Pacific configuration of NEMO is being developed based on the NOCS ORCA1 configuration (http://www.noc.soton.ac.uk/nemo/?page=configurations) with the help of Y. Lu from EC and Z. Wang from BIO-DFO. The spectral nudging scheme and open boundary conditions have been implemented with the help of D. Wright and F. Dupont from BIO-DFO. A paper describing the importance of the wind stress error covariance function in ocean data assimilation (Wakamatsu, T., M. Foreman, P. Cummins and J. Cherniawsky, On the influence of random wind stress errors on the four dimensional, mid-latitude ocean inverse problem) has been submitted to Monthly Weather Review.

The NEMO ocean model has also been implemented for the North Atlantic at Memorial University (MUN) based on the code of made available on the GOAPP website by F. Dupont, D. Wright and Z. Wang. An implementation of the Singular Evolutive Extended Kalman Filter (SEEK) is under development and is now being tested in a simulation of North Atlantic variability. Some preliminary results were presented at the CMOS meeting. The final tested version of the code is expected to be ready by the end of June 2008. Satellite altimeter observations and in-situ Argo temperature and salinity profiles for the period 1991 – 2007 have been collected, quality controlled and organized into a database at MUN.

Project I.1.4 Ocean Reanalysis and Forecasting
Co-Investigators: D. Wright, E. Demirov, M. Foreman, M. Stacey

Specific Objectives: (i) Test the ability to hindcast and forecast variability in ocean conditions using the NEMO model with various forms of data assimilation, including those developed in I.1.1-3, (ii) Use embedded finer resolution sub-domains in a North Atlantic basin model to investigate the possibility of improving specific aspects of model results through improved resolution in critical regions, (iii) Investigate the causes of variability where good agreement with observations is found, (iv) Provision of a test-bed and conduit for model improvements into the global coupled system for Theme I and, ultimately, to the operational coupled system.

Milestones for year 2 are:

- *Comparisons of prognostic model results with previous work in the North Pacific and the North Atlantic.*
- *Development of embedded finer resolution sub-domains for the regions around Cape Hatteras and the Grand Banks of Newfoundland.*
- *Initial global (1 degree) simulation with spectral nudging included.*
- *Assess the influence of spectral nudging on basin-scale circulation and watermass properties.*
- *Inclusion of the "Neptune effect" in the OPA code and examination of influence on watermass properties. Does this reduce the need for spectral nudging?*
- *Evaluation of the need for spectral nudging to be extended into the equatorial region.*

Prior to July 2007, ¼ degree North Atlantic and 1 degree global models were implemented and the basic spectral nudging code had been implemented and shown to provide results similar to those obtained with the POP model. However, comparison of results with observations did not show as good agreement with the observational estimates of mean, standard deviation and skewness of sea level.

Since July 2007:

1. We have performed several global model simulations using climatological forcing fields based on ECMWF and CORE (Common Ocean-ice Reference Experiments) forcing. The results have revealed deficiencies in both cases and have resulted in us requesting access to the DFS4 forcing fields developed by the DRAKKAR group for use in reanalysis work using the NEMO modelling system. The data were made available to us in early April at which time preparation of forcing fields for our purposes was initiated.

2. We have performed an initial simulation covering the period 1958-2004 using the 1 degree global NEMO model forced with CORE forcing fields. A particularly encouraging result is the good agreement found with the interannual to decadal variability observed at Bermuda. Previous work by Hong and Sturges using a very simple forced 1D first mode Rossby Wave model had provided excellent agreement with this data set, but our own previous work with the POP model and work by Tal Ezer using the POM model each had difficulty reproducing the observational results. It is not yet clear why our previous results with the POP model did poorly – speculations include the use of different forcing fields and the use of spectral nudging in the POP results. Examination of the reasons for this difference will be pursued if time permits. Encouraging agreement of model results with observed Halifax sea level at Halifax is also obtained for the years from 1964 to1977, but significant

discrepancies exist outside of this interval. We are now investigating the sensitivity of these results to the specified forcing fields.

3. We are currently focused on the 1 degree reanalysis work but preparing for future work using ¼ degree resolution. The latter work will require that we reduce the model domain in order to make multi-decade runs feasible on available computer resources. Work on the east coast (Dalhousie, BIO and MUN) will focus on the North Atlantic while work on the west coast (UVic and IOS) and at RMC in Kingston will focus on the North Pacific. To perform limited area simulations, we must have open boundary conditions implemented in the model and velocity and tracer results must be available from a larger scale model simulation to specify at the evolution of conditions along the open boundaries. Conditions along the open boundaries will be specified based on the results of our global reanalysis runs. The open boundary conditions made available in the standard release of NEMO were modified by Dr. Frederic Dupont to allow users to perform limited area simulations with open boundary conditions once satisfactory global 1 degree model simulations are available.

4. As an alternative to doing limited area ¼ degree simulations with specified open boundary conditions, we are also investigating the possibility of using a ¼ degree North Atlantic domain embedded within the 1 degree global model using the AGRIF (Adaptive Grid Refinement In Fortran) code. As mentioned in last year's report, this has been a problem since the AGRIF code included in NEMO did not work on our local machines. Dr. Frederic Dupont has investigated this problem and now has a version of the NEMO code including AGRIF that works on our local machines. We will consider which approach to use for ¼ degree simulations (using open boundary conditions or embedding a North Atlantic model in the 1 degree simulations) in consultation with the principal investigators working on I.1.2 and I.1.3 since the embedding approach is preferable from a dynamical viewpoint, but there are possible complications associated with using data assimilation in embedded code. This question will be investigated and a decision will be made shortly. The corrected AGRIF code will be valuable for other studies in any case.

5. We have tested the effects of spectral nudging in global and North Pacific 1 degree simulations. Results on this are preliminary, but they provide strong evidence that spectral nudging can be used to control the development of biases in the temperature and salinity fields as expected. A significant mean bias is however still present in the surface temperature field in the climatically important Pacific equatorial region. Our next step will be to consider the influence of using the DSF4 forcing fields on the surface temperatures present in the equatorial Pacific and elsewhere. If the bias persists, we will use the additional bias reduction methods developed in I.1.1 to reduce the bias to an acceptable level.

6. We have included the forcing terms corresponding to the "Neptune effect" in the NEMO model and examined its influence on model solutions. The results show that Neptune results in very significant improvements in deep conditions within the Arctic Ocean and some improvement along the western boundary of the Atlantic and Pacific basins. However, results are degraded in the eastern portion of the North Atlantic. This appears to

be related to the use of a spatially and temporally constant diffusion coefficient in the Neptune term, thus not allowing for spatial variations in eddy mixing effects. Drs. Greg Holloway and Zeliang Wang have performed some preliminary investigations of possible approaches to improving on this aspect of the Neptune forcing effect but improvements have so far been rather limited. Dr. Holloway continues to examine this question and we will work with him to test potential advances.

7. Extensions of the spectral nudging approach to the equatorial region have been investigated and are discussed under sub-project I.1.1. Spectral nudging remains the only approach that has been successful at achieving realistic Gulf Stream separation at Cape Hatteras while allowing eddy variability determined by the model dynamics. While this approach has proven to be very useful, it would be highly desirable to reduce or eliminate the need for nudging to avoid the development of model bias. This is particularly relevant to the Gulf Stream separation problem. Two possibilities are being investigated in an attempt to reduce the need for spectral nudging. First, we are examining the influence of using a biharmonic implementation of Smagorinsky mixing in the momentum equations as recently introduced by Griffies and Hallberg. Second, we are investigating a physically motivated modification of isopycnal mixing that is expected to increase the deep western boundary current and the Slope Water recirculation, and hence increase the tendency for the Gulf Stream to separate at Cape Hatteras. Preliminary results using the ¼ degree North Atlantic model are encouraging, but further work is needed to understand the influences of this approach on the model solutions. Our first test run using the modified isopycnal mixing scheme in the 1 degree global model has shown some encouraging improvements, such as a stronger deep western boundary current but the influence is rather limited. It is hoped that further improvements will be obtained after tuning an uncertain parameter associated with this new mixing scheme.

8. One quarter degree simulations with spectral nudging have been performed for both the North Atlantic and North Pacific and in both cases the results are clearly an improvement over simulations without spectral nudging. In the North Atlantic, comparisons have been made with mean, variance and skewness of sea level and in the North Pacific, comparisons have been made with interannual variations in 0 to 50 m watermass properties at Ocean Weather Station Papa. This work is ongoing.

9. Data assimilation methods are being developed at Dalhousie, Memorial and UVic for use in reanalysis work. This work is reported in detail under I.1.2. Predictability of synoptic variability in the North Atlantic has been examined using the data assimilation method developed at Dalhousie University using the POP model and shown to give very encouraging results. The method has recently been implemented in the NEMO model and is now being tuned and evaluated. Similarly, an implementation of the SEEK filter has been developed and is now being tested at Memorial University. The progress is very encouraging for future reanalysis work.

10. Gridded and raw Argo temperature and salinity data from 2002 to 2006 have been provided from the Coriolis project (http://www.coriolis.eu.org). The gridded data are used in the hindcast study of North East Pacific Ocean circulation with the developed variational data

assimilation system. The raw data are used in the assimilation systems developed at Dalhousie and Memorial Universities.

11. Mercator NEMO output for the period of 2000-2006 was obtained from Y. Lu and J. Galbraith evaluated its accuracy against Line-P observations. A report is in preparation. Y. Lu has also examined the Mercator results in comparison with climatological conditions in the Arctic and found that the results are very credible but that there are significant qualitative discrepancies that need to be resolved. Work on this is proceeding under the supervision of Lu.

12. A modified version of the NEMO code has been developed and posted on the GOAPP website for general GOAPP usage.

Project I.1.5 Modelling and Assimilation of Sea Ice
Co-Investigators: P. Myers, E. Demirov

Specific Objectives: (i) Develop a version of the NEMO coupled sea-ice ocean model for the North Atlantic incorporating data assimilation (both on the ocean and sea ice components), (ii) Validate the data-assimilative coupled ice-ocean model against observed sea-ice measurements and existing models used operationally, (iii) Examine the representation of freshwater content and fluxes in a coupled sea-ice/ocean system with sea-ice assimilation.

Milestones for Years 2-3: Evaluation of the coupled model with ice and ocean data assimilation, and comparison of different assimilation schemes.

During the past year, we have done the following.

1. We have performed a number of 1/4 degree North Atlantic simulations using the NATL4 configuration. This is the configuration developed originally by collaborator Anne-Marie Treguier, at Ifremer, Brest, France, and installed with the assistance of Sebastien Theetten, an engineer at Ifremer. These simulations allowed us to get a handle on the model configuration, as well as understand where there were limitations that needed to be focused on.

2. One focus of our simulations was the use of a sub-grid scale eddy parameterization. We implemented the form of the Gent and McWilliams parameterization that uses a variable eddy transfer coefficient, based upon the approach of Deacu and Myers (2005). Although detailed analysis is ongoing, we found that this approach led to significant improvements in the northern part of the domain, especially in the boundary currents around Greenland.

3. We examined the base sea-ice representation in the NATL4 configuration. This examination included comparisons with a 1 degree sea-ice climatology, as well as Canadian Ice Service products and estimates of thickness at several stations along the Canadian East Coast. Results are encouraging. A paper on this work has been submitted to Atmosphere-Ocean with Sanjay Rattan (Ph.D. student, now successfully defended) as first author. We also examined

the impact that oceanic assimilation through the semi-diagnostic method had on the model circulation, including sea-ice.

4. Ensembles of short simulations for each season have been performed with perturbed forcing to examine error correlations between fields for use in assimilation. The error correlation fields are now being analyzed in detail. The methodology is based upon extensive discussions with Mark Buehner of the Canadian Ice Service, whose sea-ice assimilation schemes will be employed once the correlations have been fully examined. This work is being carried out by a Ph.D. Student.

5. The SEEK filter was implemented in NEMO in preparation for use in sea-ice assimilation for the Labrador Sea.

Project I.1.6 Assessing the Capability of a Nested-Grid Shelf Circulation Model for the Eastern Canadian Shelf
Co-Investigator: Jinyu Sheng

Specific Objectives: (i) Develop a high-resolution (1/12 degree) shelf circulation model for the Eastern Canadian Shelf and embed it within a ¼ degree North Atlantic Ocean model developed by Theme I GOAPP researchers. The embedding will be achieved using a one-way nesting technique based on the semi-prognostic method developed by the applicant. (ii) Quantify the change in skill of the shelf model that results from nesting the shelf model within the deep ocean model. The metrics used to assess the model skill will focus on sea level, circulation and water mass changes on timescales of days to seasons. The model will be run in hindcast mode and the surface atmospheric forcing will be based on the best available analysis fields.

MSC student, Jorge Urrego Blanco, began working on GOAPP on June 1, 2008 reading and preparing for the development of a nested grid model.

Sub-Theme I.2 Coupled Atmosphere-Ocean Modeling and Data Assimilation

Project I.2.1 Independent Assimilation into Coupled Models
Co-Investigators: P. Gauthier, H. Ritchie

Specific Objectives: (i) Initially to achieve improvements in both atmosphere and ocean forecasts when driven by "off-line" analyses produced by uncoupled data assimilation cycles of the other component (this will provide benchmarks for examining the details of coupling behaviour), (ii) To further improve atmosphere and ocean forecasts when the component models are coupled together during assimilation cycles, but not within the analysis step, (iii) To provide coupled atmosphere-ocean fields from coupled atmosphere-ocean hindcast for sub-periods of 1993-2005, to be used in project I.2.2.

Schedule and milestones for Years 1-2:

- *Perform atmosphere only data assimilation and medium range forecasts for periods during the ocean-only forecast being done in I.1.4*
- *Establish atmospheric verification metrics to be used throughout this project*
- *Use forcing fields from Year 1 to drive the global ocean model and assimilation system*
- *Compare results with those of I.1.4 using NCEP forcing*
- *Establish ocean verification metrics for use throughout this project.*

Despite the important delay for the start of this project, the establishment of a work plan was a significant accomplishment. A meeting also took place in Halifax at the end of February 2008, to discuss the status of the efforts in the other related sub-projects associated with oceanic components. A strategy has been proposed and adopted on the design of the coupled assimilation system. In the formalism of the incremental approach to data assimilation, the assimilation components will build analysis increments independently for the atmosphere and the ocean and these corrections will be adjusted with respect to the fully coupled model. This approach will permit the use of the 4D-Var for the atmosphere and a sequential approach for the ocean analysis (see project I.1.3). The assimilation will be cycled with a 6-h assimilation window which corresponds to that used for the atmosphere. As the coupled atmosphere-ocean model is still in development, we have been involved in the development of the coupling between the GEM model and the NEMO ocean model taking place at Environment Canada. The immediate objective is to speed up the development effort to couple the GEM-global model and NEMO using the Ocean Atmosphere Sea Ice Soil (OASIS) coupler. The objective will be to have a functional system some time this summer and begin an investigation of the coupling mechanism. Atmospheric and oceanic diagnostics based on surface fluxes from the two models will be used for sensitivity studies. Progress made to date through this significant collaboration and in-kind contribution from EC and DFO is described in the following paragraphs.

Research on this component is benefiting from the CONCEPTS global coupled system development, including work on global NEMO (DFO and EC) and GEM and coupling interface (EC). For the ocean component, two versions of the ¼-deg global NEMO model have been implemented and tested on EC supercomputers in Dorval. One is the operational version consistent with that being used for the Mercator operation forecasting system; the other is the R&D version consistent with the modifications made by GOAPP researchers.

Tests of the operational version show that using the same initial condition and forcing provided by Mercator, it reproduces Mercator's result up to machine accuracy. Using GEM forcing, it obtains similar forecasts as the Mercator model driven by ECMWF forcing. This is very encouraging for the ongoing work to couple NEMO and GEM.

The research and development version has been run for six years in prognostic mode (i.e., no data assimilation) using a daily climatology of surface forcing derived from ECMWF reanalysis. This simulation is being assessed with various types of ocean observational data. The assessments show that the model produces energetic boundary currents and meso-scale eddy variability; intra-seasonal variability associated with Tropical Instability and Rossby Waves; sea-

ice distributions and motions; and seasonal variations of velocity through Barrow Strait in the Canadian Arctic Archipelago, that are consistent with observations.

Encouraged by the results from initial tests of the global NEMO model, the GOAPP and CONCEPTS researchers are moving forward to couple the global NEMO and GEM. During a discussion after the GOAPP Science Day in Halifax, it was decided that the initial step is to couple the 1-deg global NEMO developed by GOAPP to a coarse-resolution GEM. This strategy will significantly reduce the computer demand in the development stage before moving to the high-resolution coupled system. The coarse-resolution coupled system shall be directly used by GOAPP researchers for topics that do not need its high-resolution counter-part.

The coarse-resolution coupled system is expected to be in place in the early fall of 2008. Then it will be relatively easy to establish the high-resolution coupled system. The CONCEPTS team is ready for implementing the ocean data assimilation system to be imported from Mercator under the Canada-Mercator collaboration plan.

Project I.2.2 Exploratory Studies on Joint Assimilation into Coupled Models
Co-Investigators: H. Ritchie, P. Gauthier

Specific Objectives: To conduct exploratory studies to examine the use of atmosphere-ocean cross-correlation functions during the analysis step, i.e., joint atmosphere-ocean data assimilation.

Schedule and Milestones for Years 1-2:

- *Conduct diagnostic evaluation of atmosphere-ocean cross correlations based on long CGCM coupled run from project II.1.1 as outlined above.*
- *Set up and evaluate the coupled atmosphere-ocean modelling system consisting of the GEM atmospheric model and simplified ocean model. Perform the control simulation of the twin experiment and extract "synthetic observations" from both the atmosphere and ocean.*

Following a long search to find an appropriate postdoctoral fellow for this sub-project, Dr. Faez Bakalian was hired effective July 1, 2007.

Dr. Bakalian quickly started on the first milestone noted above by conducting an exploratory statistical analysis of the covariance structure of joint atmosphere-ocean variables. Fields from the long CGCM coupled run from the Canadian Centre for Climate Modeling and analysis were provided by Dr. Bill Merryfield. In addition to the CGCM fields, global fields of Sea Surface Temperature (SST) and Sea Level Pressure (SLP) from an NCEP reanalysis were also studied. An Empirical Orthogonal Functions (EOF) analysis of the joint SST-SLP CGCM output was conducted and compared with the corresponding results from the NCEP reanalysis. Power spectra of the amplitudes and coherency diagrams for the 3 dominant modes were computed. Similarly, Redundancy Analysis (RA) was carried out for SLP forcing SST (and vice versa) and their respective power spectra were computed. The results of both statistical techniques were compared to identify similarities and differences. In all case studies, SLP was found to be the

principal forcing agent, leading SST by about 1 month. Propagating components of the ENSO SST signal from the Pacific to the Atlantic Ocean were also identified in the RA of both the CGCM output ant the NCEP reanalysis. RA was also used to explore the effect of SLP on SST for the North Atlantic region on monthly to seasonal time scales. A tripole SST anomaly was identified in the 1st mode of the North Atlantic RA and found to be associated with the strengthening and weakening of the Azores and Icelandic pressure systems. These results have been presented at several workshops and conferences, and will soon be submitted for publication. The title of the paper is "Coupled principal component and redundancy analyses of global SST-SLP data fields" by Bakalian, F., H. Ritchie, K. Thompson and W. Merryfield, 2008, submitted to Journal of Climate.

As a transition between this initial study and the second milestone noted above, a simple coupled state space model has been constructed and configured to mimic a coupled atmosphere-ocean system. EOF and RA analyses are being performed on coupled outputs and cross-correlations are being assessed in preparation for conducting a twin experiment to assess the value of joint assimilation in this idealized system.

Theme II: Seasons to Decades

The broad reach of Theme II research has been reflected in progress on a broad front. The research is proceeding on what might be called an "end-to-end parallel track". The "parallel track" expression indicates that investigations and activities are advancing simultaneously, rather than sequentially, on many aspects of Theme II research. The "end-to-end" aspect reflects the research approach that proceeds from the analysis of model results and the comparison with observations, to model improvements, to investigations of predictability, to methods of initializing the coupled system, to the generation of ensembles of seasonal (and ultimately decadal) forecasts which are analyzed, verified, and even improved upon via post-processing.

The reports below indicate that this approach is being successfully followed and that considerable progress has been made. For example, an extensive set of retrospective ensemble seasonal forecasts has been completed with a version of the CCCma coupled model that was available at the start of the GOAPP Network activities. The 12-month forecasts, initialized 4 times per year from 1972, are serving as a baseline skill measure against which the impacts of model and initialization improvements can be assessed.

The forecast results have been compared against results from the 2-tier HFP2 retrospective forecast experiment, done by the CLIVAR Network, which form the basis for the current operational CMC seasonal forecast system. The results are encouraging in that, in spite of being our first effort with a coupled model, the forecast skill at one-month lead exceeds that of the 4-model HFP2 forecast skill for some seasons.

We expect progress to continue in the next year and also that we will deepen our connections with Theme I research by providing coupled model data for Theme I investigations and through investigations of spectral nudging in the ocean component of the coupled model for potential use in seasonal forecasting.

Finally, Theme II research has and will continue to have a considerable international aspect with contributions to and analyses of the international coupled model archives (such as CMIP3), to participation in the WCRP/WGSIP Climate system Historical Forecasting Project (paralleling our CHFP), and to IPCC/WCRP decadal forecasting efforts among others.

Sub-Theme II.1 Analysis and Mechanisms

Project II.1.2 Pacific Decadal Oscillation and Northern Annular Mode
Co-Investigator: J. Fyfe, J. Derome, Wm. Merryfield

Specific Objectives: To understand and improve the representation of the dominant large-scale modes of tropical/extratropical variability in the CCCma coupled climate model (primarily), with a particular focus on the role these modes play in enhancing or limiting predictive skill at various time scales in the Northern Hemisphere.

Years 1-2 Milestones:
Data collection to include observations, CCCma coupled model control simulations and a multi-model ensemble of results from IPCC models contributing to the AR4.

Careful analysis and documentation of model behaviour and errors in the simulation of mean climate and in the simulation of the key modes of Northern Hemisphere tropical/extratropical variability in the ensemble of model results, including the behaviour of the "mean model".

This project primarily concerns the evaluation of systematic errors in the simulation of North Pacific atmospheric and oceanic surface climatology and variability. Observational data and output from most of the World's global climate models has been assembled, and a detailed intercomparison has been completed. F. Lienart, the PhD student, responsible for this project, is writing a paper describing the results obtained so far. The paper is entitled "A comparison of North Pacific sea surface temperature climatology and variability in the World's global climate models" and will be submitted in a few months to either the Journal of Climate or Atmosphere-Ocean. In addition to meeting the scheduled milestones some additional work has been accomplished on assessing the change in North American surface climate predictability in a warmer world. F. Lienart has been working closely with John Fyfe and to a lesser extent with G. Boer and S. Kharin.

Sub-Theme II.2 Predictability of the Coupled System

Project II.2.1 Potential Predictability of Current and Future Climates
Co-Investigators: G. Boer, W. Merryfield

Specific Objectives: (i) Undertake a multi-model diagnosis of potential predictability of present-day climate using coupled climate model output (including that of CCCma CGCM3) submitted to IPCC Fourth Assessment, (ii) Extend the diagnostic study of potential predictability to include

effect of climate change, (iii)Quantify regional influences on predictability in integrations in which ocean feedbacks are suppressed in key regions such as the tropical Pacific, the North Pacific, and the North Atlantic.

Schedule and Milestones:

Years 1 and 2: Collect data from IPCC data archive for multi-model potential predictability calculation for control and climate change simulations, transform to common grid, and perform multi-model potential predictability analysis.

Progress continues to be made on this project. Decadal potential predictability analyses of the current climate simulated by some 27 models in the CMIP3/IPCC archive has been undertaken and the results published in the paper entitled "Multi-model decadal potential predictability of precipitation and temperature" (Boer and Lambert, 2008). The results indicate that decadal predictability of temperature may be found mainly over middle to high latitude oceans with only very modest potential predictability, at these timescales, in the tropics and over land. Precipitation shows, perhaps not surprisingly, even less predictability on these timescales with predictability confined to the high latitude North Atlantic and the Southern Ocean.

Results of further analysis, not yet prepared for publication, show that, perhaps surprisingly, the *internally generated* decadal potential predictability (i.e., that remaining after removing the externally forced component) decreases with global warming. The results are being written up for publication. G.J. Boer gave an invited presentation on the potential predictability results at the Second International conference on Earth System Modelling in Hamburg, and an oral presentation at the European Geophysical Union Congress in Vienna

The potential predictability results are of interest for the expanding WCRP/IPCC attention to multi-decadal prediction and G.J. Boer is an invitee to the Aspen Global Change Institute's Workshop "Climate Prediction to 2030". He is, in addition, a member of the WGCM/WGSIP/CLIVAR/WCRP subgroup preparing an international proposal for "Coordinated Experimentation in the Study of Multi-decadal Prediction and Near-term Climate Change".

Substantial progress has been made by Merryfield and PDF, Dr. Ajayamohan, on objective (iii), (originally a Year 3 to 4 milestone, but moved forward for reasons detailed below) in which predictability is diagnosed in CCCma climate model runs in which a "partial coupling" procedure is implemented switch off air-sea coupling in specified regions. Within these regions, the atmospheric model is provided with a climatological annual cycle of SST obtained from the freely-running model, whereas the ocean continues to "see" the atmosphere. The necessary coding modifications have been implemented, and long model runs are underway in which this procedure is implemented globally, and in North Pacific, tropical Pacific, eastern tropical Pacific, equatorial Pacific, and Indian Ocean regions. Analyses of differences in climate variability and its predictability in these various cases are underway. Preliminary results were presented by Ajayamohan at the CMOS Congress in Kelowna.

Project II.2.2. Prognostic predictability from ensembles of coupled model simulations
Co-Investigators: W. Merryfield and G.J. Boer

Specific Objectives: (i) Obtain measures of prognostic predictability through "perfect model" predictability experiments based on large ensembles of coupled model integrations, (ii) Investigate influence of initial climate regime on seasonal-to-decadal predictability

Schedule and Milestones:

Year 1: Set up computational machinery for constructing and running large ensembles for "perfect model" experiments. Begin computing large ensemble of 10 year runs starting from neutral ocean initial conditions.

Year 2: Complete computation of large ensemble of 10 year runs starting from neutral ocean initial conditions, continue subset of these runs to 50 years. Develop diagnostic tools and carry out analyses of prognostic predictability in these ensembles.

PDF Ajayamohan R. S. was hired effective September 4, 2007, coming to CCCma with considerable experience in studies of observed and modeled tropical climate variability and predictability.

As detailed below, following previously reported Year 1 progress important model improvements were implemented and their impacts evaluated by co-investigator Merryfield. This has led to improvements in model performance that are significantly enhancing the value of modeling activities under II.2.1, II.2.2 and II.3.2.

For reasons given below, Year 2 milestones under II.2.2 were moved to Year 3, compensated by advancing Year 3-4 milestones under II.2.1 to years 2-3. PDF Ajayamohan has made strong progress in the preparation, execution, and analysis of the associated coupled model runs in which air-sea coupling is modified in specified regions. In an additional investigation Drs. Ajayamohan, Merryfield and Kharin found that the increasing occurrence of extreme rainfall events associated with the South Asian Monsoon, as well as their interannual variations, are attributable to changes in synoptic activity, which potentially can be represented by ensemble forecasts or inferred indirectly from forecasts of other quantities such as SST. A publication describing this work has been submitted.

Sub-Theme II.3 Prediction

Project II.3.1 Coupled Model Initialization
Co-Investigators: G. Flato and W. Merryfield

Specific Objectives: (i) Investigate and implement several relatively simple ocean initialization schemes in a global coupled model, (ii) Evaluate the relative merits of these methods in terms of the realism of initialization products, the severity of initial "coupling shock", and the skill of bias-corrected coupled forecasts, (iii) Having established the fidelity of the methods and

optimized them, to use them as a basis for generating an ensemble of initial conditions for the CHFP.

Schedule and Milestones:

Year 1: Continue nudging experiments and test forecasts, following on from CLIVAR activity. Begin assembling 3-D data sets and initiate collaborative work on 2D-Var and semi-prognostic methods.

Year 2: Analyze test forecasts made with nudging scheme; prepare paper on initial results. Begin experiments with 2D-Var and semi-prognostic methods. Begin implementing sub-sea extension of SST assimilation. Consider atmospheric initial states constrained by analyses, assess impact on forecast skill.

The initial set of test forecasts, initialized using a simple SST nudging and based on an "off the shelf" model version available when this effort began under CLIVAR, has been completed (see II.3.2).

The proposed application of relatively simple variational data assimilation methods to 3D ocean initialization has progressed on several fronts, largely through the efforts of Research Associate, W.-S. Lee. Seven analyses of monthly mean 3D ocean temperatures covering the period from 1980 to present have been imported to CCCma and regridded onto the CCCma ocean model grid. An extensive intercomparison of these analyses has been carried out, demonstrating the extent to which multiple analyses can provide a diversity of ocean initial conditions within observational constraints; these results are being prepared for publication. Using one of these reanalyses as input to a 2D-var assimilation procedure adapted from code provided by collaborator Tang, several sets of test retrospective forecasts were carried out in which parameters associated with the assimilation procedure were varied. Each of these forecast sets showed substantial skill improvement in predicting ENSO (El Niño-Southern Oscillation) as compared to a comparable set of forecasts initialized with SST nudging, and based on the skill differences between these forecast a set of optimal parameters for the Tang assimilation procedure was selected.

Using this 2D var assimilation procedure, seven sets of single retrospective forecasts for 1980-2002, one for each ocean analysis, have been produced. Properties of this forecast ensemble, in particular the ensemble spread, are being compared against those of two comparable ensembles initialized using (i) atmospheric, and (ii) ocean initial conditions drawn from consecutive dates preceding the start of the forecast, with the objective of quantifying how the diversity of ocean initial conditions provided by assimilating of multiple analyses impacts the evolution of the ensemble. These initial investigations using the 2D Var assimilation procedure were described in an oral presentation by Lee at the CMOS Congress.

Progress has also been made on developing and implementing models of the ocean background error covariances that are more sophisticated than the simple, commonly used form employed under the Tang procedure. Under this approach, the covariance properties of ocean temperature variability are determined directly from the temperature variability in the model, using this relatively complete information as a proxy for the very sparse observations of the 3D ocean.

Two such procedures have been developed based on different covariance models in the literature. The objective will be to apply these approaches to ocean initialization in the model, comparing skill against the simpler Tang procedure.

The semi-prognostic method for ocean initialization was removed from further consideration due to the departure from GOAPP of Co-Investigator Greatbatch.

Efforts to implement a more sophisticated atmospheric initialization have also progressed. Because the SST nudging procedure employed thus far does not provide a detailed picture of the true "weather" at the start of the forecast period, skill in the first month of the forecast period is badly degraded in comparison to HFP2, in which the atmosphere was initialized by inserting (regridded) atmospheric reanalyses. With the aim of improving atmospheric initialization in the coupled forecasts, S. Kharin has developed a procedure for obtaining ensembles of atmospheric initial conditions from NCEP reanalyses. With the objective of going further and assimilating (rather than inserting) observations in the AGCM (Atmospheric General Circulation Model), a collaboration has been initiated with Saroja Polavarapu and colleagues at EC Downsview to apply their data assimilation expertise to this problem.

Work has begun on developing a web-based system for the dissemination of coupled seasonal forecast results.

Tang and coworkers at the University of Northern British Columbia have investigated a new ensemble-based Kalman filter, called Sigma-Point Kalman filter (SPKF), for data assimilation of strong nonlinear dynamical systems. The SPKF data assimilation scheme is compared against standard Kalman filters such as extended Kalman filter (EKF) and ensemble Kalman filter (EnKF) schemes, using the Lorenz model. Three particular cases, namely the state, parameter, and joint estimation of states and parameters from a set of discontinuous noisy observations are studied. It has been found that the SPKF is capable of estimating model state and parameters with better accuracy than EKF and EnKF for strong nonlinear systems. This work has been accepted by J. Atmos. Sci. (pending revision). Next step, the SPKF will be proposed to use for the assimilation of OGCM (Oceanic General Circulation Model).

Project II.3.2 The Coupled Model Historical Forecasting Project
Co-Investigators: G. Boer, J. Derome, W. Merryfield, and G. Flato

Specific Objectives: (i) Produce a sequence of retrospective multi-seasonal ensemble forecasts using the CCCma coupled atmosphere-ocean-land-ice model and to extend a subset of these forecasts to the decadal range, (ii) Investigate methods of generating ensembles of initial conditions and of forecasts, possibly including multi-analysis and multi-model approaches, (iii) Obtain basic skill measures of multi-seasonal forecasts produced in this way and some insight into the possible utility of predictions at longer times, (iv) Analyse and identify, to the extent possible, those aspects of the forecast system that impact on predictive skill.

Schedule and Milestones:

Years 1 and 2: Initial forecast experiments to assess and refine the CHFP approach to be adopted including ensemble generation, data assimilation, forecast production and initial verification methods.

An extensive set of retrospective ensemble forecasts, initialized using SST nudging and employing the coupled model version that was available at the time this effort started under CLIVAR funding, has been completed through the efforts of Research Associate, W.-S. Lee. This forecast set, designated as the Coupled Historical Forecast Project, version 1 or CHFP1, has served as a platform for developing computational infrastructure, processing capability, and verification measures applicable to a second "production" set of coupled forecasts (tentatively CHFP2) that will employ model and initialization improvements developed under GOAPP (see below). The CHFP1 forecasts, which comprise 12-month, 10-ensemble forecasts initialized 4 times per year from 1972 to 2001 (1200 model years in all), are also serving as a baseline skill measure against which the impacts of model and initialization improvements can be assessed.

The CHFP1 forecast results have been comprehensively evaluated and compared against results from HFP2 using analysis tools developed by S. Kharin. Although CHFP1 forecasts at zero-month lead suffer from the lack of a detailed atmospheric initialization as described under II.3.1, forecast skill at one-month lead in some cases exceeds that of the 4-model HFP2 forecast set, e.g. for winter surface temperatures over Canada which are strongly impacted by ENSO, whereas HFP2 remains more skillful in other cases such as Canadian surface temperatures in summer. Equatorial Pacific SST is forecast more skillfully than under the persistence assumption employed by HFP2, especially after the first season, demonstrating the utility of coupled model forecasts at longer leads. The CHFP1 forecast results are described in a publication under preparation and in an oral presentation by Merryfield at the CMOS Congress.

Efforts to improve CCCma's coupled forecast system from this CHFP1 baseline, in addition to the initialization improvements detailed under II.3.1, have included improvements to the physics and vertical resolution of the ocean model component, and implementation of more realistic, time-varying radiative forcing to represent the influence of evolving radiative forcing agents such as greenhouse gases.

Tang's work in this sub-theme includes 1) analyzing Atmosphere-Ocean (AO) ensemble forecast by CCCma GCM2 and McGill SGCM, and ENSO ensemble forecast by our hybrid coupled models; 2) exploring possible measures of potential predictability of AO and ENSO. It has been found that relative entropy and the ensemble mean square are good predictors in quantifying climate prediction skill. Two papers have recorded these studies.

Project II.3.3 Forecast Combination, Calibration and Verification
Co-Investigators: Jacques Derome, G. Boer and W. Hsieh

Specific Objectives: (i) Comprehensive and sophisticated analysis of the skill of CHFP forecasts at time scales of interest including the geographical distribution of skill and the connection to

known dynamical modes, (ii) Development of sophisticated post-processing methods to improve skill of global coupled model forecasts including the development of probability forecasts and their calibration in single- and multi-model ensemble settings, (iii) Assessment of potential economic value in a cost-lost decision framework.

Year 2: Evaluate the true predictive skill of CCA forecasts in multi-century simulations with CGCM3 and other global climate models. Test post-processing techniques on available seasonal dynamical forecasts with the aim of improving their skill.

A 1000-yr control simulation of CGCM2 is employed to assess the reliability of skill score estimates of CCA-based seasonal forecasts in Canada. The evaluation is done for the CCA model that uses global SSTs as predictor for Canadian surface air temperature. Cross-validated skill score estimates obtained by withholding 1, 3, and 5 years are compared to the out-of-sample skill score estimates obtained on independent samples. Results of the study show that the cross-validated skill score estimates for CCA-based seasonal temperature forecasts are severely inflated. Skill inflation does not decrease when more that one year are withdrawn in cross-validation. The results of this study are documented in Shabbar and Kharin (2007).

A number of post processing strategies have been evaluated in retrospective forecasts using four global atmospheric models which form the basis for the current Canadian operational system. Several methods of combining multimodel output to produce deterministic and probabilistic forecasts of near surface air temperature, 500-hPa geopotential height, and 700-hPa temperature for 0-month and 1-month leads were considered. A variance-based rescaling of hindcasts from different models improves skill slightly in some cases. The parametric probability estimator based on a normal distribution is found to be superior to the nonparametric count-method estimator for producing multimodel categorical probability forecasts. A statistical adjustment of the multimodel ensemble mean and of the ensemble spread is found to be beneficial for hindcasts of near surface temperature over oceans but not always over land. Skill tends to improve with the number of models used for a given total ensemble size. This work is described in Kharin et al. (2008).

Boer and Hamilton (2008) investigate the influence of the Quasi-Biennial Oscillation (QBO) on extratropical predictive skill in HFP2 results. The state of the QBO may be predicted with considerable skill for many months. The study indicates that taking account of the QBO could provide additional, although modest, skill centred in the region of the North Atlantic Ocean.

A related analysis of HFP2 data (Boer, 2008) indicates that the long-term trends seen in reanalysis data for the 30 year period covered by HFP2 is weak in the forecasts themselves. One hypothesis is that the lack of explicit greenhouse gas forcing in the forecast models is a cause, even though the HFP2 two-tier forecasts include this information implicitly in the SSTs and in the initial conditions. It is apparently possible to improve forecast skill over regions of Eurasia by introducing the observed trend in the forecasts but not, unfortunately, over North America. A lack of Greenhouse Gas (GHG) forcing might be expected to have a larger effect on the coupled CHFP forecasts than on the HFP2 forecasts. In the latter case, some effects of GHG forcing are contained implicitly in the SSTs while this is not the case for the coupled forecasts. We expect to include GHG, and perhaps other external forcing agents, in forthcoming CHFP calculations.

A study has been done by H. Lin, G. Brunet and J. Derome (Lin et al., 2008) to see if a statistical post-processing of seasonal forecasts could be developed to correct some of their systematic errors and thus improve their skill. A post-processing technique has been applied to the forecasts of the surface air temperature and of precipitation. The tests were conducted on the global forecasts. As far as the Canadian and North American continental regions are concerned the following conclusions can be reached. The post-processing cannot improve the better-quality forecasts, but it does improve the lower-quality predictions.

Tang and co-workers explored several recently proposed information-based measures of predictability, including relative entropy (R), predictive information (PI), predictive power (PP), and mutual information (MI), in terms of their ability of estimating a priori the predictive skill of the ENSO ensemble predictions. It was found that the MI is a good indicator of overall skill. When it is large, the prediction system has high prediction skill, whereas small MI often corresponds to a low prediction skill. This suggests that MI is a good indicator of the actual skill of the models. The R is a better predictor of prediction skill than PI and PP, especially when correlation-based metrics are used to evaluate model skill. This study led to one publication.

New machine learning methods have been tested by Hsieh's group, and a new Post Doctoral Fellow, Joel Finnis, was hired on 1 June, 2008. Work is underway to apply machine learning methods (neural networks, support vector machines, etc.) to nonlinearly post-process the CHFP model forecasts, especially the seasonal extremes.

Project II.3.4 Sensitivity of Seasonal Climate Forecasts in the CCCma GCM to Initialization of Land Surface Hydrological States
Co-Investigator: A. Berg

Specific Objectives: To characterize the importance of accurate specification of the land surface hydrological state for seasonal prediction, with a particular focus on land surface initialization for drought prediction.

This particular component of this project began on January 3, 2008. The specific milestone for the first year of this project aims to produce a global data set of land surface initial soil moisture conditions, generated by the Canadian Land Surface Scheme (CLASS) using a bias-corrected meteorological forcing and perform an assessment of the realism of the product. To this end, G. Drewitt, a research associate has been hired to assist in the development of the forcing and CLASS simulations and Master's student, L. Courtney, has been recruited to perform the evaluation of the soil moisture initial states.

We have obtained the NCEP/NCAR reanalysis data and have acquired the necessary global observation datasets of surface temperature, precipitation, radiation and humidity. We are working on the bias correction procedures for these two variables. At the CMOS meeting in May 2008 we presented a soil moisture sensitivity study to precipitation bias in CLASS.

1.2 EXPLAIN ANY SIGNIFICANT DELAYS OR DEPARTURES FROM THE RESEARCH PLAN, OR THE RESCHEDULING OF ACTIVITIES, AND HOW THEY WERE ADDRESSED.

Overall the research is on track and no major delays or departures have occurred. There were some minor delays and challenges as detailed below:

1. Problems with implementing the NEMO ocean model code: Initially, the NEMO code did not work on our local machines. Three months of focussed effort by F. Dupont were required to modify the open boundary code and to resolve code portability issues in the AGRIF code. These efforts slowed his progress and delayed the start of the work on the SEEK filter.

2. Challenges with the North Pacific NEMO code: The code has proven to be a challenge to keep running after modification. After the 0.25 degree prognostic version of ocean model code was running successfully, we found that including spectral nudging was (for technical reasons) not a trivial task. Also, the open boundary of the model near the equator has caused problems, in the sense that the simulated, mean, surface level of the Pacific Ocean could unrealistically increase monotonically with time. These problems appear to have been overcome.

3. Delay due to switching ocean models: The completion of a variational data assimilation system for a simplified ocean model was delayed due to switching from the simple ocean circulation model provided from M. Yaremchuk (University of Hawaii) to a simplified version of NEMO. The change arose because the Yaremchuk model proved to be difficult to modify. This switch caused an approximate 6 month delay in applications by M. Foreman and T. Wakamatsu to the North Pacific and global ocean.

4. Delay due to coupled atmosphere-ocean model improvements: Following initial progress described in last year's report, using a developmental version of the CCCma climate model, a decision was made to postpone generating the planned large ensembles of runs until important model improvements could be implemented. The improvements included subsurface penetration of solar radiation, modifications to the mixed-layer parameterization, and improved vertical resolution in the ocean, as well as applying a spatial filter to atmospheric physical parameterizations. These changes have substantially reduced model SST biases and improved the mixed-layer depth and surface current climatologies, as well as properties of the modeled tropical variability, from which much of seasonal-to-interannual predictability is expected to derive. To compensate for moving the Year 2 milestones for II.2.2 to Year 3, the Year 3 to 4 milestones for II.2.1 (involving suppressing modeled ocean-atmosphere feedbacks in key regions) have been advanced to Years 2 to 3, and substantial progress has been made in this area as described under II.2.1.

5. Delays due to long search for personnel: Due to the long delay in finding a suitable postdoctoral fellow for sub-project I.2.2, it started 9 months after the official beginning of the GOAPP network. Very good progress has been made during this first year of our research and development activity, as reported above, but nevertheless we estimate that we are about 6 months behind our original schedule. Some of the delay is being addressed by using an

idealized system to develop our intuition on joint assimilation into coupled atmosphere-ocean models while awaiting the availability of a coupled GEM-NEMO system. Similarly, the PDF position at UQAM was not filled until late January 2008 by Dr. Sergey Skachko. Dr. Sckachko was a post-doctoral fellow at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. Previous to that he had been a postdoctoral fellow at the Laboratoire des Ecoulements Géphysiques et Industriels (LEGI) in Grenoble, France where he worked on the estimation of atmospheric forcing parameters for the global NEMO ocean model using a Kalman filter. His past experience will enable him to get up to speed rapidly with the atmosphere-ocean coupled system that will use the NEMO ocean model.

6. Delay due to difficulties installing the GEM atmosphere model: During this reporting period, Y. Tang was to begin working on the set-up of a coupled atmosphere-ocean modelling system consisting of the GEM atmospheric model and a simplified ocean model under the second milestone. Installation of the GEM model on his local computer has begun, but has been delayed due to complications arising from the fact that this is the first time that an installation of GEM has been attempted on this particular type of computing platform. It will be important to resolve this technical issue in the near future, or for this work to be done on another platform on which the GEM model code is already available.

7.
Delay due to course requirements: Progress on the error correlation study and application to the sea-ice assimilation at the University of Alberta has been delayed due to heavier than anticipated course requirements.

1.3 EXPLAIN SIGNIFICANT DEVIATIONS FROM THE BUDGET. (NOTE: CHANGES OF 20% OR MORE FROM BUDGET CATEGORIES REQUIRE ADVANCE APPROVAL FROM THE CFCAS SECRETARIAT).

The SSC and the Board of Directors approved the following budget deviations.

1. Release of funds: A major deviation has been the release of $45,000 from G. Flato's budget over the next two years of the Network. The Scientific Steering Committee will be recommending the reallocation of these funds to the Board of Directors. It is anticipated that some of this money will be used to support Data Archiving and Data Management as well as exchange visits between various GOAPP institutes.

2. Delayed start time: The search for an appropriate postdoctoral candidate to work with E. Demirov at MUN took longer than expected. This resulted in a late start for the funded part of the project. The SSC agreed to allow E. Demirov to use the accumulated funds to support a graduate student.

3. Reallocation of funds: H. Ritchie reported that due to the late start of F. Bakalian, resulting surplus funds have been budgeted into increased travel and dissemination costs in the remaining years. Extra travel to conferences and workshops to publicize our R&D results are

anticipated. It is also likely that more journal articles will be produced than expected earlier. The GOAPP Board of Directors has approved the budget as revised.

4. Use of Post Doc rather than graduate student: W. Hsieh reported that he will be using a post-doc J. Finnis (starting 1 June, 2008) to carry out the work originally proposed for a graduate student, as this will allow the project to spin-up quicker.

5. Use of Research Associate rather than Post Doc: P. Gauthier reported that given Dr. Skachko's experience, he had to be hired as a research assistant which is more expensive than the salary of a postdoctoral fellow. However, the unspent funds from the previous year will permit to cover this higher salary for the whole duration of the project.

6. Reallocation of Funds: W. Merryfield reported that the approved revised budget reallocates funds originally targeted for PDF salary prior to the September 2007 arrival of Dr. Ajayamohan to travel and publication costs in the remaining years of the network.

7. Reallocation due to late start: D. Wright reported that some funding made available by the late start in the first year was used to support a second research associate to work full time on the GOAPP project for about 2 months.

1.4 DESCRIBE HOW THE WORK OF CO-INVESTIGATORS WAS INTEGRATED OR COORDINATED.

Overall the integration and coordination of the research was good. One encouraging trend is the strengthening of collaborations between themes, and across disciplines. This bodes well for the success of the network and the training of the next generation of coupled modellers. Details of the integration and coordination are given below.

At the Network level, six Co-Investigators are members of the Scientific Steering Committee (SSC). The SSC acts as an important integrating mechanism among projects and between the two Themes. Rotation of committee members was accomplished with the retirement of D. Wright and G. Flato from the SSC. They were replaced by Co-Investigators M. Foreman and W. Merryfield respectively. Principal Investigators, Hal Ritchie and Keith Thompson hold formal meetings with Network Manager, Susan Woodbury, on a weekly basis.

The GOAPP researchers in the Halifax-Dartmouth area established an approximately bi-weekly discussion group at Dalhousie University. Both E. Demirov and T. Wakamatsu gave presentations during their visits. All talks are made available on the GOAPP webpage and are listed in Section 3 of this report.

Investigators and collaborators at CCCma at the University of Victoria held bi-weekly meetings to discuss progress and coordinate efforts. Co-Investigator Tang provided computer code being used for ocean data assimilation and ongoing technical advice, and visited CCCma in July 2007. Collaborator Scinocca is the principal contact with the Downsview atmospheric data assimilation group and is facilitating technical aspects of this collaboration.

The GOAPP Network sponsored a Science Day on February 28, 2008 in Halifax. This was an opportunity to brief the GOAPP Board of Directors on the science being tackled by the network researchers. Close to 35 people from GOAPP Themes I and II, the Board of Directors, Environment Canada, Fisheries and Oceans Canada and the Department of National Defence attended the all day meeting. The agenda can be found at Appendix D.

The GOAPP Annual workshop took place in Kelowna on 25 May 2008. The workshop and the subsequent CMOS Annual congress provided an excellent opportunity for GOAPP researchers to review progress and encourage collaboration both internally, with other networks (e.g., DRI) and also with fellow Canadian and international scientists.

Some individual activities are listed below:

1. P. Myers travelled to Halifax and St. John's to interact with the GOAPP investigators in those cities to discuss model developments, applications and plans. He interacted by email with investigators in the Canadian Ice Service on development of the error correlation approach. He also attended the DRAKKAR workshop in France to discuss modelling results and strategies for experiments with DRAKKAR consortium scientists.

2. F. Bakalian, H. Ritchie and K. Thompson met frequently at Dalhousie University to plan, discuss results, and monitor the progress of this sub-project. Interactions with W. Merryfield and P. Gauthier are mostly be e-mail, and occasionally by telephone. Productive meetings were held in person when W. Merryfield and P. Gauthier came to Halifax to participate in our GOAPP Science Day at the end of February 2008. Overall, the integration and coordination are working well.

3. D. Wright has updated the NEMO model code. New modules (e.g., the spectral nudging code) have also been made available to all GOAPP researchers through the GOAPP web site and individuals have been given assistance using it when requested.

4. E. Demirov visited Dalhousie University for a week in December, 2007 to work with K. Thompson, D. Wright, Y. Lu, F. Dupont and Z. Wang. The groups in MUN, Dalhousie and BIO exchanged information periodically about developments in each group.

5. Productive meetings were held in person when P. Gauthier and S. Skachko came to Halifax to participate in the GOAPP Science Day at the end of February 2008 and stayed for one more day to discuss with Keith Thompson, Dan Wright, Hal Ritchie and other researchers the integration and coordination of the project. This was a very fruitful meeting that helped everybody to get a good overview of the direction the project is headed.

6. T. Wakamatsu from UVic/IOS and Yunfeng Shao from RMC have each visited Dalhousie/BIO to accelerate technology transfer and to discuss future developments and collaborations. Discussions have focused on ocean model and data assimilation developments and prospects for coordinated reanalysis work. M. Foreman visited BIO in November 2007 and discussed NEMO issues with D. Wright and Y. Lu.

7. M. Stacey reported that D. Wright's group has been very helpful in providing assistance in getting the NEMO code running at HPCVL, and in implementing the spectral nudging. Yunfeng Shao found his visit to BIO in the summer of 2007 to be very useful.

8. Predictability analysis of partially coupled model runs by W. Merryfield and Ajayamohan will use software tools developed by G. Boer for his investigations.

9. The group at BIO had developed routines for setting up the model and preparing forcing fields and shared this expertise with co-investigators at Dalhousie, MUN, UVic/IOS and RMC. This group also assisted other groups with implementation of the NEMO code. The BIO group is currently doing 1 degree global reanalysis runs and will provide open boundary conditions to other groups wishing to do limited area simulations. Research Associates from BIO, RMC and UVic are in frequent contact to share developments.

1.5 DESCRIBE THE PARTICIPATION OF GOVERNMENT (FEDERAL, PROVINCIAL OR MUNICIPAL), UNIVERSITY, INDUSTRY, FOREIGN OR PRIVATE SECTOR RESEARCHERS (AND/OR OTHER STAFF) INVOLVED IN THE PROJECT.

Government (Federal, Provincial, Municipal): The participation of government researchers in the project continues to be excellent. Seven of the Co-Investigators are adjunct professors and are fully engaged in research and development. Nineteen government collaborators are involved in a variety of capacities. (See Appendix B) During this reporting period, Pierre Gauthier changed his employment from Environment Canada to the Université du Québec à Montréal (UQÀM) where he has become increasingly involved in GOAPP. In addition, the following activities were reported:

1. Simulations by A. Berg with the CLASS model have been completed with assistance and input from Dr Paul Bartlett (Environment Canada). In particular, he has been helpful in providing access to the code and documentation. He is also accessing data from the Canadian Precipitation Analysis project (CaPA) from Environment Canada's Hydrometeorology and Arctic Laboratory. Dr Bruce Davison has been facilitating access to this dataset.

2. Since four of our co-investigators (Hal Ritchie (EC), Dan Wright (DFO-BIO), Mike Foreman (DFO- IOS) and Keith Thompson (Dalhousie) are involved in the inter-agency initiative to develop a Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS), we have quite naturally coordinated our work with researchers within DFO and EC. Work on ocean model developments is closely coordinated between GOAPP investigators and related federal government activities. As EC moves into the use of coupled Ocean-Atmosphere modelling, we anticipate that this coordination will be further strengthened in order to meet the challenges ahead. We are also coordinating our reanalysis work with researchers in the UK (Greg Smith) and in the French DRAKKAR initiative (Bernard Barnier and the DRAKKAR group).

3. Close ties have also been maintained with DFO's new Centre for Ocean Model Development and Application (COMDA); D. Wright and M. Foreman are on the COMDA scientific

steering committee as well as being involved as theme leaders and SSC members for GOAPP.

4. P. Myers reports interactions with Mark Buehner of the Data Assimilation and Satellite Meteorology Research Section of EC on assimilation plans and approach, as well as acquiring Canadian Ice Service data to use for assimilation and validation.

5. Some GOAPP researchers are partially funded by government. For example, T. Wakamatsu receives 50% of his salary from DFO and works part time at DFO-IOS and approximately 90% of Z. Wang's salary is provided by COMDA and other DFO project funds.

University: With the addition of Co-Investigator, A. Berg, from the University of Guelph, there are now ten universities participating in the GOAPP project. Each university provides office space and computing facilities for GOAPP researchers.

The NEMO ocean model has also been implemented at HPCVL (http://www.hpcvl.org) and on ACEnet machines (http://www.ace-net.ca/). HPCVL and ACEnet are university-based consortiums that provide high performance computing resources. Each group has received support from the Canadian Foundation for Innovation and other organizations.

Industry, Foreign or Private Sector: We have made the spectral nudging method known to the French-based Mercator and DRAKKAR groups and let them know that we will help them to use the method if requested (D. Wright). Also, collaboration with Anne-Marie Treguier, Arne Biastoch and other DRAKKAR scientists on best approaches for NATL4 NEMO simulations was reported. (P. Myers)

IMPACT

1.6 WHAT SHORT AND MEDIUM TERM OBJECTIVES HAVE BEEN ACHIEVED, OR ARE ANTICIPATED;

The major advances made by GOAPP over the reporting year are listed below (order unimportant).

- A computationally efficient method for the simultaneous assimilation of Argo and altimeter data has been developed and shown to provide useful forecast skill. A manuscript has been submitted for publication. The rapid progress made on this sub-project is primarily responsible for the submission of a supplementary proposal to CFCAS to support the development of a pre-operational ocean forecast system for the North Atlantic and the transfer of GOAPP technology to the CONCEPTS initiative.

- The MSST of the North Atlantic and the second and third moments of sea level variability have been made available to other GOAPP researchers for purposes such as tuning of model parameters for optimal performance.

- A numerical model of the Labrador Sea has been developed that has 1/12th degree horizontal resolution and is two-way nested into a ¼ degree North Atlantic Ocean model. This model is presently being used for hindcast and data assimilation studies of the Labrador Sea.

- A data assimilation scheme based on the Singular Evolutive Extended Kalman filter has been developed and validation of the method is underway.

- Tangent linear and adjoint codes required for the development of a variational data assimilation system have been written.

- Significant progress has been made on the assimilation of sea ice into the NEMO model using a simple 1 dimensional approach. Numerous small changes in parameterizations, parameters and forcing have been made to improve the simulations. It is expected that the inclusion of sea-ice assimilation will significantly improve the quality of the sea-ice representation off the east coast of Canada.

- One quarter degree versions of the NEMO ocean model have been implemented for the North Atlantic, North Pacific and Arctic domains on various machines across Canada – ACEnet, HPCVL, IOS and CMC – both in prognostic and nudged mode, and simulations are in progress.

- The AGRIF nesting technology has been made to work on the machines available to us, paving the way for future work on using targeted finer resolution in regions of interest.

- Spectral nudging has been shown to work well in the NEMO code and code modifications have resulted in the ability to reduce the strength of this intrusion on model dynamics without resulting in overshooting of the Gulf Stream, a common and important problem in most eddy admitting ocean models.

- A first global reanalysis using a 1 degree model has been completed using CORE forcing covering the period 1958 to 2005. Initial comparisons with observations of sea ice, hydrographic variability in the Labrador Sea and sea level variations at Halifax and Bermuda are encouraging. A new hybrid forcing referred to as DFS4 has been obtained from the DRAKKAR Group in France and will be used in the next reanalysis run. Improvements are expected since this data set has been determined to minimize the development of biases in NEMO simulations.

- A ¼ degree North Atlantic reanalyses has been prepared for using open boundary conditions that are either determined from the 1 degree global simulation or embedding of the basin model in a new 1 degree simulation using the AGRIF technology. We will soon be able to make results from the reanalysis runs available to colleagues in the CONCEPTS initiative and will collaborate with them on the analysis of these results.

- Ocean reanalysis work to date has used prognostic simulations only. Development of the data assimilation systems under GOAPP projects is proceeding well and new methodologies are expected to become available for use in reanalysis work during the coming year.

- The diagnostic evaluation of atmosphere-ocean cross-correlations in a long coupled CGCM run has been achieved and we are starting preparations for a twin experiment to assess the value of joint assimilation in an idealized system.

- The development of a bias-corrected meteorological forcing dataset that will meet the goal of producing a dataset of bias-corrected soil moisture is anticipated by the end of 2008.

- The investigation of South Asian Monsoon extreme rainfall events has linked their occurrence to changes in synoptic activity that are potentially more predictable by forecast models.

- The multi-model predictability investigation by Boer and Lambert, using 8000 years of data from 21 climate models, has characterized climate potential predictability with improved statistical confidence compared to previous investigations, and has produced the first multi-model estimate of long timescale potential predictability of precipitation. Further work is characterizing the impact of global warming on climate predictability.

- The partial coupling work by Merryfield and Ajayamohan is anticipated to provide a clearer picture of how air-sea interactions in specific regions contribute to climate variability and predictability.

- An initial set of ensemble coupled retrospective forecasts (CHFP1), comparable in scope to HFP/HFP2, has been produced. Comparison of skill with 2-tier HFP2 forecasts has demonstrated advantages of coupled forecasting. The CHFP1 forecasts also provide a baseline for assessing the impact of ongoing improvements to the coupled forecast system (model, initialization, post-processing).

- Each of the historical forecast investigations reported here has developed post-processing strategies that improve the value of seasonal forecasts.

- Model initialization is a key element of any dynamical forecast system, and very significant progress is being made toward improved initialization of the ocean, atmosphere and land (see II.3.4) model components as compared to the very simple SST nudging procedure used to facilitate initial progress. Significant skill improvements have already been demonstrated to result from the use of ocean data assimilation.

1.7 DESCRIBE THE SIGNIFICANCE / IMPACT OF THE RESULTS ACHIEVED TO DATE AND HOW THIS NEW KNOWLEDGE HAS INFLUENCED RESEARCH POLICY, ENHANCED RESEARCH COLLABORATION OR COMPETITIVENESS, OR HELPED ATTRACT OR TRAIN SKILLED PERSONNEL.

Address the following items, as appropriate:

- **The impact of the project on government policy development (federal, provincial or municipal);**

The GOAPP network is part of an interagency initiative to develop an operational ocean modelling capability in Canada (CONCEPTS). Further discussions with CONCEPTS researchers regarding the use of spectral nudging in the coupled system that is being developed have confirmed that this method will be used at least initially to control the development of model bias.

- **How the project has expanded contacts in partner organizations, or increased cross-disciplinary cooperation;**

  Links with DFO and EC research scientists have improved significantly over the last year due to GOAPP. There have also been encouraging interactions between research scientists from CCCma (most notably W. Merryfield) on the west coast and oceanographers (university and DFO) on the east coast.

  D. Wright reported that his project has contributed to increased collaborations with UK researchers through coordinated research involving Greg Smith, a research associate working with Keith Haines at Reading.

- **Whether and how it has improved the reliability of predictive methods;**

  A proposal has been submitted to CFCAS to establish a pre-operational North Atlantic Ocean forecast system over the next two years, based on assimilation and model codes developed as part of GOAPP.

  Work on improved parameterizations has resulted in new approaches that significantly reduce the need for data assimilation in the form of spectral nudging. Improvements on this approach will be considered during the coming year, with a particular interest in eliminating the need for this approach in long-term simulations. Note however that we expect that our predictive simulations of synoptic variability will continue to benefit from the use of this method.

- **The impact of the project on your own institution;**

  The Network has increased the number of highly qualified personnel in all of the partner institutions. At RMC, this project has benefited graduate students and has increased the profile of oceanography and high performance computing within the Physics Department. Graduate student activity, started as follow-on to a previous but related CFCAS grant for which the POP was used, has in turn aided this project.

  At RMC, M. Stacey's group is currently the heaviest user of HPCVL resources, and as such he is a member of the HPCVL Technical Advisory Committee.

  At Dalhousie University, the home of the Network Secretariat, the GOAPP initiative continues to be positively received by the senior administration and they anticipate that it will raise the profile of ocean and atmospheric research at Dalhousie and in Canada.

- **Whether and how the project has helped increase funding from other agencies, or led to new partnerships;**

  As mentioned above, the research of the GOAPP network has led to a proposal to CFCAS for supplementary funding to develop North Atlantic Ocean, and global coupled forecast systems to be run in pre-operational model. The funding request is for $98K for each of two years.

- **Any current (or potential) commercial or social applications, which the results may have;**

  Not applicable.

- **Links with international initiatives and the potential impact of these;**

  Coordination of activities with the Mercator operational center in Toulouse, France and the European DRAKKAR Research and Development group has continued. Dr. Eric Dombrowsky, Scientific and Technical Director, of MERCATOR OCEAN is an active member of the GOAPP Board of Directors. He came to Halifax in February 2008, where he gave an "Overview Presentation on Mercator Activities" and participated in the Board of Directors' Meeting. He reinforced our efforts for cooperation with his organization.

- **Anticipated benefits of the work for Canadians.**

  Ultimately GOAPP will lead to better predictive models of the marine environment. The main potential for benefit to Canadians is through improved prediction skill being transferred to the inter-agency CONCEPTS initiative. Improved knowledge of the state of the atmosphere and ocean from global coupled models and data assimilation systems is a critical need for science and for several government departments (including EC, DFO and DND). Improved predictions on time-scales from days to decades can have both immediate and long-term societal benefits, despite the difficulty in their production and, in some cases, modest skill. The Network will also make important contributions to the development of research capacity and the training of personnel in coupled atmosphere-ocean forecasting. This is essential if Canada is to remain internationally competitive in this field and also have the capability of making the best possible forecasts in response to national needs.

2 LEVEL OF SUPPORT

2.1 WHAT PROPORTION OF THE TOTAL BUDGET WAS PROVIDED BY CFCAS?

In most cases, CFCAS has provided full support for students, Post Doctoral Fellows and Research Associates. However, in a few cases there have been significant contributions from other sources. For example, CFCAS funds 90% of F. Dupont's salary, 50% of T. Wakamatsu's salary and 10% of Z. Wang's salary. The remainder of the salaries for these individuals are covered by DFO. CFCAS provides full travel and publication support for Dupont and Wakamatsu while DFO covers these costs for Wang.

All host universities and government departments provide funds for desktop computers, office space, computing and telephone services and supplies. Salaries of the co-investigators were supplied by their home institutions.

2.2 ANY ADDITIONAL OR 'MATCHING' RESOURCES THAT WERE SECURED OR COMMITTED TO THE PROJECT: SOURCES AND AMOUNTS, AND WHETHER THEY WERE FURNISHED AS AGREED (ON SCHEDULE AND IN THE AMOUNTS AGREED).

The following additional or matching resources were reported:

1. Funds from an ongoing CFCAS project awarded to E. Demirov are used to support a graduate student, who works on the data collection and analysis needed for this project. Computer facilities, purchased as a part of a Canadian Foundation of Innovation award to E. Demirov are used extensively by the present project.

2. About 60% of the work done under this project at BIO was supported by DFO A-base or B-base funding as contributions to both the CONCEPTS and GOAPP projects. T.Wakamatsu (IOS) received approximately 50% support from the DFO Centre for Ocean Model Development and Analysis (COMDA) program. Overall, about 55% of the support for work done at BIO and IOS has been provided by DFO. The contribution from DFO has met or exceeded expectations.

3. The Master's student working on the evaluation of soil moisture initialization in CLASS is funded partially from an NSERC discovery grant to Dr. Aaron Berg.

4. PhD Student Sanjay Rattan had an NSERC scholarship, as well as a teaching assistantship from the University of Alberta.

5. Undergraduate student Khoa Nguyen received some funds from the University of Alberta International centre as part of their goal to get more international undergraduate students working in relevant areas on campus.

6. P. Myers is using some of his NSERC Discovery Grant funds to support NEMO NATL4 model development – i.e., any improvements in the prognostic versions of the model will be applied to the data assimilation studies conducted here under GOAPP.

7. Additional funding for Tang ($15K/year) is covered by the University of Northern British Columbia start-up and Canada Research Council funds.

8. W. Hsieh reported that about half of the post-doc's salary will be funded by his NSERC discovery grant.

9. The annual fee ($5000.00) for access to HPCVL is provided by another research grant obtained through RMC.

2.3 DESCRIBE IN-KIND CONTRIBUTIONS RECEIVED FROM COLLABORATORS OR SPONSORS AND, IF POSSIBLE, THEIR ESTIMATED VALUE (E.G. EXPERTISE OF FEDERAL OR OTHER SCIENTISTS, FACILITIES, TECHNICAL SUPPORT, ETC.).

Secretariat: DFO and Dalhousie University have continued to contribute to the running of the Network Secretariat (e.g., phone charges, furniture).

Computer Resources: A major contribution in-kind has been computer resources provided by government partners. Without these resources it would be impossible to undertake the Network's research. Equally important have been the computer resources made available to us by the ACEnet, HPCVL and WestGrid consortiums. The annual fee ($5000.00) for access to HPCVL is provided by another research grant obtained through Royal Military College. All institutes are providing basic facilities, including personal computers, for both co-investigators and support personnel at no extra cost. Also note that significant computer resources have been purchased by E. Demirov with funds supplied by the Canadian Foundation for Innovation.

Model Development: Much of the Theme II research is based on the most recent version of CCCma's CGCM3 coupled climate model (T63, no flux adjustment, new ocean physics). The time of numerous CCCma researchers contributing to the development and the computing resources in Victoria and Dorval are paid for by Environment Canada.

Similarly, much of the Theme I research is based on a recent version of the NEMO model made available by the NEMO developers group and a significant part of the NEMO model implementation has been carried out by DFO researchers (under COMDA). GOAPP received limited technical support from Sebastien Theetten and Jean-Marc Molines – France, DRAKKAR consortium for new model developments, as well as diagnostic code.

Support by Government Researchers: Both Environment Canada and Fisheries and Oceans Canada have allowed some of their most experienced and effective researchers to contribute directly to GOAPP research. DFO personnel (D. Wright, Z. Wang and M. Foreman) and Environment Canada personnel (H. Ritchie, P. Pellerin, S. Bélair, G. Boer, Y. Lu, W. Merryfield, J. Fyfe, S. Kharin, G. Flato and J. Scinocca) have been extensively involved in the GOAPP Network. Dr. S. Lambert of CCCma contributed by downloading and formatting IPCC data.

2.4 DESCRIBE TRANSFER OF FUNDS TO CO-INVESTIGATORS: TO WHOM AND WHERE? HOW DID THE CO-INVESTIGATOR(S) REPORT ON THE FUNDS USED; AND WERE INTER-INSTITUTIONAL AGREEMENTS USED.

Funds were transferred from Dalhousie University to the Co-Investigators on a quarterly basis. Dalhousie required each participating university to sign a letter of agreement prior to releasing the funds to the institution. The amount of funds transferred was in accordance with the request of the Co-Investigator for the specific time period.

The list of Co-Investigators and their affiliation can be found in Appendix B. Only J. Sheng and W. Hsieh did not request funds during this reporting period.

2.5 INDICATE ANY OUTSIDE FACILITIES USED DURING THE PROJECT (E.G. METEOROLOGICAL INSTRUMENTS, RESEARCH LABORATORIES, SHIP TIME, ETC.) AND DESCRIBE THE ARRANGEMENT.

The GOAPP Network relies on the use of outside computing resources such as ACEnet high performance computing resources, HPCVL, IOS, BIO, MUN, EC, CCCma, UVic and Dalhousie computers. The user fee for HPCVL is paid by RMC. Computer facilities are available through internet connections. To help understand some model results, we have received output from a global ¼ ORCA025 simulation run at Grenoble. This experiment was run on super-computing facilities in France.

Evaluation of soil moisture simulation and realism in CLASS are being assessed using instrumentation and meteorological instruments operated by Alberta Environment and instruments purchased by Dr. Berg through a Canadian Foundation for Innovation and Ontario Research Fund grants and maintained with an NSERC discovery and strategic grants to Dr. Berg.

3 DISSEMINATION

3.1 PROVIDE INFORMATION ON DISSEMINATION OF THE RESEARCH RESULTS (PUBLICATIONS, INCLUDING JOURNAL NAMES AND WHETHER REFEREED), CONFERENCE CONTRIBUTIONS, SEMINARS, WORKSHOPS OR VIDEOS, WEBSITES OR OTHER METHODS OF TRANSFERRING THE RESULTS.

GOAPP Publications

Ajayamohan, R. S., W. J. Merryfield and V. V. Kharin 2008: Increasing trend of synoptic activity and its relationship with extreme rain events over central India. *Geophys. Res. Lett.,* submitted.

Ambadan, T. J., and Y. Tang, 2007: Sigma-point Kalman Filters for the assimilation of strongly nonlinear systems. J. Atmos. Sci. (under the second-round review).

Bakalian, F., H. Ritchie, K. Thompson and W. Merryfield, 2008: Coupled principal component and redundancy analyses of global SST-SLP data fields, submitted to Journal of Climate.

Bacon, S., P.G. Myers, B. Rudels and D.A. Sutherland, 2008: Accessing the inaccessible: Towards an understanding of subarctic shelf processes In "Arctic - Subarctic Ocean Fluxes: Defining the Role of the Northern Seas in Climate", R.R. Dickson, J. Meincke and P. Rhines (eds), Springer, 703-722.

Barnier, B. L. Brodeau, J. Le Sommer, J-M Molines, T Penduff, S Theetten, A-M Treguier, G Madec, A Biastoch, C. Boning, J. Dengg, S. Gulev, R. Bourdalle Badie, J. Chanut, G. Garric, S. Anderson, A. Coward, B. de Cuevas, A. New, K. Haines, G. Smith, S.

Drijhout, S. Hazeleger, C. Severijns and P.G. Myers, 2007: Eddy-Permitting Ocean Circulation Hindcasts Of Past Decades, Clivar Exchanges

Boer, G.J., 2008: Climate trends in seasonal forecasts. Submitted to Atmos-Ocean.

Boer, G.J. and K. Hamilton, 2008: QBO influence on extratropical predictive skill. Climate Dynamics. doi:10.1007/s00382-008-0379-5.

Boer, G. J., and S. J. Lambert, 2008: Multi-model decadal potential predictability of precipitation and temperature, Geophys. Res. Lett., 35, L05706, doi:10.1029/2008GL033234.

Kharin, V. V., Q. Teng, F.W. Zwiers, X. Zhang, G.J. Boer, J. Derome, 2008: Skill assessment of seasonal hindcasts from the Canadian Historical Forecast Project (to be submitted).

Lin, H., G. Brunet and J. Derome, 2008: Seasonal forecasts of Canadian winter precipitation by post-processing GCM integrations. Mon. Wea. Rev., 136, 769-783.

Rattan, S.S.P. and P.G. Myers, 2008: Sea ice representation in the NATL4 configuration of NEMO, submitted to Atmosphere-Ocean

Shabbar, A., and V. V. Kharin, 2007: An assessment of cross validation for estimating skill of empirical seasonal forecasts using a global coupled model simulation. CLIVAR Exchanges, 12, 10-12.

Tang, Y. and B. Yu, 2008: MJO and its relationship to ENSO. J Geophys Res,doi:10.1029/2007JD009230.

Tang, Y. and B. Yu, 2007: An analysis of nonlinear relationship between the MJO and ENSO. J. Japan Met. Soc. (under second-round review)

Thompson, K. R., J. Huang, M. Veronneau, D. G. Wright and Y. Lu, 2008: The Mean Surface Topography of the North Atlantic: Comparison of Estimates based on Satellite, Terrestrial Gravity and Oceanographic Observations. Submitted to the Journal of Geophysical Research

Thompson, K., Y. Liu, 2008: Predicting Mesoscale Variability of the North Atlantic Using a Physically-Motivated Scheme for Assimilating Altimeter and Argo Observations, Submitted to Mon. Wea. Rev.

Wakamatsu, T., M. Foreman, P. Cummins and J. Cherniawsky, 2008: On the influence of random wind stress errors on the four dimensional, mid-latitude ocean inverse problem. Submitted to Mon. Wea. Rev, April 2008.

Oral and Poster Presentations/Conference and Workshop Proceedings

Ajayamohan, R. S., and W. J. Merryfield, 2008: Regional influences of ocean-atmosphere interaction on climate variability assessed using partial coupling. CMOS Congress, Kelowna, BC 26-29 May 2008.

Ambadan, J. T. and Y. Tang, 2008: Advanced Data Assimilation in Strongly Nonlinear Systems via Sigma-point Kalman Filters. CMOS Congress, Kelowna, BC 26-29 May 2008

Dombrowsky, E., 2008: Overview Presentation on Mercator Activities, GOAPP Science Day, Halifax, 28 February 2008.

Bakalian, F., 2008: Modes of Variability of the coupled atmosphere-ocean system: Redundancy analysis of global sea surface temperature and air pressure. GOAPP Discussion Group, Halifax, NS, 31 January, 2008.

Bakalian F., H. Ritchie, K. Thompson and W. Merryfield, 2008: Redundancy Analyses of the coupled atmosphere-ocean system. GOAPP Science Day, Halifax, 28 February 2008.

Bakalian F., H. Ritchie, K. Thompson and W. Merryfield, 2008: Modes of Variability of the coupled atmosphere-ocean system: Redundancy analysis of global sea surface temperature and air pressure. Presentation at the European Geosciences Union General Assembly in Vienna, Austria, April 13-18 2008.

Bakalian F., H. Ritchie. K. Thompson and W. Merryfield, 2008: Regional and Global Scale Redundancy Analyses of the Coupled Atmosphere-Ocean System (presentation 3C5.6). CMOS Congress, Kelowna BC, 26-29 May, 2008.

Berg, A. and G. Drewitt, 2008: Sensitivity of Seasonal Climate Forecasts in the CCCma GCM to Initialization of Land Surface Hydrological States, DRI Workshop, Calgary, AB, 17-19 January, 2008.

Berg, A, 2008: Review of New Project: Seasonal Climate Forecasts and Land Surface Processes; GOAPP interaction with the CFCAS-funded DRI Research Network. GOAPP Network Workshop, Kelowna BC 25 May, 2008

Boer, G.J., 2008: Changes in the decadal-scale potential predictability of the coupled system with global warming. CMOS Congress, Kelowna BC, 26-29 May, 2008.

Boer, G.J., 2008: Multi-model decadal potential predictability of temperature and precipitation. European Geosciences Union General Assembly 2008 Vienna, 13 – 18 April 2008

Boer, G.J., Decadal multi-model potential predictability. Invited Presentation at the Second International conference on Earth System Modelling, Max-Planck-Institut fur Meteorologie. Hamburg, 27-31 Aug., 2007.

Cheng, Y. Y. Tang and X. Zhou, 2008: The Singular Vector (SV) Analysis of an ENSO Prediction Model for the Period from 1856-2003. CMOS Congress, Kelowna BC, 26-29 May, 2008.

Demirov, E., 2007: Data Assimilation in the GOAPP North Atlantic model. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 18 December 2007.

Demirov, E., K. Thompson, and D. Wright, 2007. GOAPP- Canadian network for Global Ocean-Atmosphere Prediction and Predictability: Data assimilation in the North Atlantic Ocean model. NATO Advanced Research Workshop, "Challenges before the Black Sea operational oceanography to increase the regional environmental security", Varna, Bulgaria.

Demirov, E., and M. Cooke, 2007: Model study of coupled sea-ice interannual variability in the Labrador Sea, Second International Conference on Earth System Modeling, Hamburg.

Demirov E., J. Zhu, M. Hakobyan, 2008: Data assimilation in a regional ocean model of the Labrador Sea. CMOS Congress, Kelowna, BC 26-29 May 2008.

Deng, Z. and Y. Tang, 2008: Decadal/Interdecadal variations in ENSO predictability in a hybrid coupled model from 1881-2000. CMOS Congress, Kelowna, BC 26-29 May 2008.

Donohue, S.M, M.W. Stacey, and J.A. Shore, 2008: Rossby Waves and the North Pacific Current. CMOS Congress, Kelowna, BC 26-29 May 2008.

Drewitt, G. and A. Berg, 2008: Comparison of precipitation fields over Canada estimated from reanalysis products. Poster presentation, CMOS Congress, Kelowna, BC 26-29 May 2008.

Dupont, F., 2008: Optimized Parameters and Updated Code. GOAPP Science Day, Halifax, NS, 28 February 2008.

Dupont, F., D. Wright, Z. Wang and K.R. Thompson, 2008: Sensitivity study of the North Atlantic circulation. What are the optimal parameters or parameterizations in NEMO? CMOS Congress, Kelowna, BC 26-29 May 2008.

Gauthier P., 2008: Theme I project I.2.1. GOAPP Science Day, Halifax, NS, 28 February 2008.

Higginson, S., 2008: Climatologies Based on De-Eddied Profile Data. GOAPP Science Day, Halifax, NS, 28 February 2008.

Hsieh, W., 2008: Presentation of Upcoming Project: Forecast Combination, Calibration and Verification. GOAPP Network Workshop, Kelowna BC 25 May, 2008

Jia, S., H. Lin and J. Derome, 2008: Improving seasonal forecast skill in Canada using a post-processing method. CMOS Congress, Kelowna, BC 26-29 May 2008.

Kharin, S., 2008: Review and Discussion of Theme II (Continued). GOAPP Network Workshop, Kelowna BC 25 May, 2008

Lee, W.-S., W. J. Merryfield and Y. Tang, 2008: Initialization of Coupled Seasonal Forecasts by Assimilation of an Ensemble of Ocean Reanalyses. CMOS Congress, Kelowna, BC 26-29 May 2008.

Lienert F. and J.C. Fyfe, 2008: North Pacific Sea Surface Temperature Climatology and Variability in the World's Global Climate Models. CMOS Congress, Kelowna, BC 26-29 May 2008.

Liu, Y, 2008: Predicting Mesoscale Ocean Variability using a New Scheme for Assimilating Altimeter and ARGO Data. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 15 January, 2008.

Liu, Y. and K. Thompson, 2008: Assimilation of Data into Ocean Models: On-Line Estimation of Background Error Covariance Parameters. CMOS Congress, Kelowna BC, 26-29 May, 2008.

Liu, Y., 2008: Online Bias Correction and Background Error Covariance Estimation for Ocean Models. GOAPP Science Day, Halifax, NS, 28 February 2008.

Lu, Y., 2007: Global Ocean Modelling for GOAPP and CONCEPTS. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 9 October, 2007.

Lu, Y., J-M Bélanger, F. Roy, H. Ritchie, D. Wright, Z. Wang, F. Dupont, G. Holloway and G. Garric, 2008: Initial assessment of the CONCEPTS global ½-deg ocean and sea-ice model (presentation 4B5.2). CMOS Congress, Kelowna BC, 26-29 May, 2008.

Merryfield, W. J., G. J. Boer, Greg Flato, Viatcheslav Kharin, Woo-sung Lee, Badal Pal, John Scinocca 2008: The Coupled Historical Forecast Project, version 1: Formulation, results, and progress towards CHFP2. CMOS Congress, Kelowna, BC 26-29 May 2008.

Merryfield, W. J., 2008: Progress report on coupled seasonal forecasting at CCCma. GOAPP Science Day, Halifax, NS, 28 February 2008.

Merryfield, W. J., 2008: Review and Discussion of Theme II (Analysis and mechanisms, predictability, coupled model initialization and forecast, forecast post-processing and verification). GOAPP Network Workshop, Kelowna BC 25 May, 2008

Merryfield, W. J., 2008: Theme II Overview. GOAPP Science Day, Halifax, 28 February 2008.

Myers, P.G., 2007: The West Greenland Current and the Labrador Sea, Memorial University, St. John's

Myers, P.G., 2007: Numerical Modelling in the North Atlantic using SPOM Sea Water Formation, Dalhousie, University, Halifax

Myers, P.G., 2007: The West Greenland Current and the Labrador Sea, Bedford Institute of Oceanography, Halifax

Myers, P.G., 2008: Sea Ice and Hydrography in the Labrador Sea: Impact of the East Greenland Current and Tidal Mixing, Drakkar Workshop, Grenoble, France

Myers, P.G., 2008: West Greenland Current and Labrador Sea Variability, 1949-2005, Kiel, Germany

Myers, P.G., 2008: West Greenland Current and Labrador Sea Variability, Ouranos, Montreal

Oliver, E., 2008: Connections Between the Madden Julian Oscillation and Extratropical Regions of the Global Ocean and Atmosphere. CMOS Congress, Kelowna BC, 26-29 May, 2008.

Oliver, E. 2008: Extra Tropical Expressions of the MJO. GOAPP Science Day, Halifax, NS, 28 February 2008.

Oliver, E., 2007: The Madden-Julian Oscillation: An overview of the physical processes and possible connections with northern high-latitude weather and climate. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 13 November 2007.

Ritchie, H., 2008: Overview of (GOAPP) Theme I. GOAPP Science Day, Halifax, NS, 28 February 2008.

Ritchie, H., 2007: Plans for coupling and coupled data assimilation in GOAPP, and interactions with Mercator and CONCEPTS. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 23 October, 2007.

Ritchie, H., 2008: Theme I projects I.2.2 and I.1.5. GOAPP Science Day, Halifax, NS, 28 February 2008.

Ritchie, H., F. Davidson, J. Loder, Y. Lu, P. Pellerin, W. Renaud, M. Taillefer, K. Thompson and D. Wright, 2008: Recent Developments for an Operational Canadian Global Assimilation and Prediction Capability for the Coupled Atmosphere-Ocean-Ice System. GOAPP Science Day, Halifax, NS, 28 February 2008.

Ritchie, H., F. Davidson, J. Loder, Y. Lu, P. Pellerin, W. Renaud, M. Taillefer, K. Thompson and D. Wright: Recent Developments for an Operational Canadian Global Assimilation and Prediction Capability for the Coupled Atmosphere-Ocean-Ice System (presentation 4B5.1). CMOS Congress, Kelowna BC, 26-29 May, 2008.

Ritchie, H. and P. Gauthier, 2008: Review of Theme I.2 (coupled modeling and assimilation) and the CFCAS supplement. GOAPP Network Workshop, Kelowna BC 25 May, 2008

Shao, Y. and M. Stacey, 2008: Simulating the Northeast Pacific Ocean using OPA. Poster Presentation, CMOS Congress, Kelowna BC, 26-29 May, 2008.

Shore, J.A., Stacey, M.W. Wright, D.G., 2007: Eddy Energy Sources in the Northeast Pacific Ocean, International Union of Geodesy and Geophysics. Perugia, Italy, July 2-13, 2007.

Sheng, J., 2008: Review of New Project: Shelf Downscaling. GOAPP Network Workshop, Kelowna BC 25 May, 2008

Tang, Y., and J. T. Ambadan, 2008: Ensemble based data assimilation, International Workshop on Data Assimilation, Banff, 2008, Feb 3 – 8.

Tang, Y., and J. T. Ambadan, 2008: Advanced Data Assimilation in Strongly Nonlinear Systems via Sigma-point Kalman Filters. EGUnion General Assembly, Vienna, 13 – 18 April 2008

Tang, Y., 2008: Review and Discussion of Theme II (Continued). GOAPP Network Workshop, Kelowna BC 25 May, 2008

Turnbull, M. and P. Myers, 2008: Towards sea ice assimilation in NEMO: Background Error Covariances. Poster Presentation CMOS Congress, Kelowna, BC 26-29 May 2008.

Thompson, K. R., 2007. Mean Sea subsurface Topography of the North Atlantic. Seminar Series at Bedford Institute of Oceanography.

Thompson, K. R., 2007. Mean Sea subsurface Topography of the North Atlantic: Oceanography and Geodesy Collide. Centre for Climate Change Science, Symposium Series, University of Toronto.

Thompson, K. R., 2008. Assimilation of Argo and Altimeter Data into Eddy Resolving Ocean Models. Workshop on Mathematical Aspects of Data Assimilation, Banff International Research Station, Banff, Canada.

Thompson, K.R., 2008: Theme I projects I.1.2 and I.1.3. GOAPP Science Day, Halifax, NS, 28 February 2008.

Wang, Z., D. Wright, Y. Lu, G. Holloway and F. Dupont, 2008: The effects of eddy parameterization in a coarse-resolution global ocean and sea-ice model. CMOS Congress, Kelowna, BC 26-29 May 2008.

Wakamatsu, T., 2008: Development of 4DVAR system for simplified OPA and implementation of Green's Function method to NEMO, GOAPP Discussion Group, Dalhousie University, Halifax, NS, 03 April, 2008:

Wakamatsu, T. and M. Foreman: The inverse modeling of the seasonal variation of the Eastern North Pacific Ocean circulation. CMOS Congress, Kelowna, BC 26-29 May 2008.

Wakamatsu, T., M. Foreman, and K. Thompson, 2008: Tangent Linear Approximation of Ocean Mixed Layer Model. CMOS Congress, Kelowna, BC 26-29 May 2008.

Wright, D.G., 2007: Ocean Prediction, Regional to Global: Goals, Progress and Challenges, Dalhousie Oceanography Departmental seminar, 30 October, 2007

Wright, D.G., 2008: Review and Discussion of Theme I.1 (Ocean Data Assimilation and Sea Ice Modelling) 5 projects, GOAPP Network Workshop, Kelowna BC 25 May, 2008

Wright, D.G., 2008: Theme I projects I.1.1 and I.1.4. GOAPP Science Day, Halifax, NS, 28 February 2008.

Wright, D., Z. Wang, F. Dupont, K.R. Thompson and Y. Lu, 2008: Progress in Modelling Gulf Stream Separation with an Eddy Admitting Model. CMOS Congress, Kelowna, BC 26-29 May 2008.

Zhang, X, 2007: Response of the Tropical Pacific Ocean to the Madden-Julian Oscillation. GOAPP Discussion Group, Dalhousie University, Halifax, NS, 27 November, 2007.

3.2 DESCRIBE DATA MANAGEMENT/SHARING ACTIVITIES INCLUDING ORGANIZATION OF THE METADATA. ALSO IS THE DATA BEING ARCHIVED, AND HOW WILL IT BE MADE AVAILABLE TO OTHER RESEARCHERS?

The Data Management Committee (DMC) is working on developing a strategy for the distribution of GOAPP data on the web and for the management of large volumes of data both during the network's activities and after the network completes its mandate. To that end, the DMC has canvassed the Co-Investigators to get a better understanding of their data requirements and with a view to preparing a proposal for the use of some of the funds which G. Flato has relinquished to address the data archiving.

GOAPP purchased a 500 GB server which resides at Dalhousie University. It is used to host the current version of the NEMO code. Users can access this information through the password-protected NEMO Users Forum on the GOAPP web site.

D. Wright reported that Coriolis analysis (gridded and raw Argo data) are available from Coriolis project (http://www.coriolis.eu.org). Data can be obtained through ftp by submitting a request to codac@ifremer.fr. D. Wright's model simulations are being archived on the mass storage system at BIO.

P. Myers reported that all of his team's model simulations are being archived on Westgrid's gridstore data server at Simon Fraser University. Model results are being shared with DRAKKAR consortium members in Europe.

G. Flato reported that all results from experimental coupled system seasonal forecasts are archived on the 'central file system' (CFS) at Environment Canada's supercomputing facility in Dorval. An undergraduate student has been hired to facilitate sharing of coupled model output (principally coupled seasonal forecasts) and metadata on the web.

G. Boer reported that much of the research in II.3.3 has drawn on the publicly available HFP2 retrospective forecasts.

The GOAPP Data Management Committee (DMC) consists of: J. Chaffey (DFO), W. Merryfield (GOAPP Co-Investigator), M. Ouellet (DFO), H. Ritchie (GOAPP PI), K. Thompson (GOAPP PI), Lt. (N) D. Williams (DND) and S. Woodbury (GOAPP Network Manager)

3.3 COMMENT ON ANY OUTREACH OR PUBLIC INFORMATION ACTIVITIES, INCLUDING PRESS INTERVIEWS OR OTHER MEDIA INTEREST OR REPORTS. HAS THE PROJECT HELPED TO POPULARIZE SCIENCE OR INCREASE PUBLIC AWARENESS?

After numerous talks with Kelly Crowe of CFCAS, it was decided that an official launch would not attract enough interest to warrant the level of effort required.

The GOAPP Science Day provided us with the opportunity to publicize GOAPP in government circles, specifically to Environment Canada, Fisheries and Oceans Canada and the Department of National Defence.

P. Myers, in his role as President of the Canadian Meteorological and Oceanographic Society (CMOS), has been involved in the work that the Society has done to publish statements on the science of climate change, and the importance of further research in these areas. In addition, he presented GOAPP material to an undergraduate class when talking about science programs.

M. Stacey has recently agreed to participate in an outreach program involving local schools as part of the HPCVL Consortium.

4.4 HOW HAVE YOU ACKNOWLEDGED SUPPORT FROM CFCAS?

Most GOAPP presentations and publications and journal articles formally acknowledge CFCAS as the primary funding agency. The CFCAS logo is often displayed on the first pages of power point presentations, on posters and in other appropriate locations. The CFCAS logo is also prominently displayed on the GOAPP website at www.goapp.ca and interested people can follow a link to the CFCAS website.

4.5 ATTACH COPIES OF ANY PAPERS PUBLISHED OR ACCEPTED FOR PUBLICATION.

The following papers are attached:

Ajayamohan, R. S., W. J. Merryfield and V. V. Kharin 2008: Increasing trend of synoptic activity and its relationship with extreme rain events over central India. *Geophys. Res. Lett.,* submitted.

Tang, Y. and B. Yu, 2008: MJO and its relationship to ENSO. J. Geophys. Res,doi:10.1029/2007JD009230.

4 TRAINING

4.1 QUANTIFY STUDENT AND POSTDOCTORAL INVOLVEMENT IN THE PROJECT, INDICATING THE NUMBER OF: UNDERGRADUATE, MASTERS, DOCTORAL OR PDFS. ALSO SUMMARIZE THEIR ROLES IN THE PROJECT.

Undergraduate Student: 3

H. Ashworth (Berg) Project II.3.4. She will assist with the soil moisture observations in the summer of 2008 (Not funded by GOAPP.)

K. Nguyen (Myers) – Project I.1.5. He was an undergraduate BSc student working part time in the lab, assisting with computer systems, visualization of results and data preparation and analysis. Graduated in the spring of 2008 and has gone to work in industry.

N. Wu (Flato) – Project II.3.1 - He is implementing sharing of coupled forecast data over the web.

Masters Student: 5

J. T. Ambadan (Tang) – Project II.3.1. He is working on the theoretical side of data assimilation, i.e., developing and studying novel assimilation methods.

Jorge Urrego Blanco (Sheng) – Project I.1.6. He began on June 1, 2008, reading and preparing for the development of a nested grid model.

L. Courtney (Berg) – Project II.3.4. Working on evaluation of the realism of soil moisture processes in CLASS. (Not funded by GOAPP)

M. Hakobyan (Demirov) – Project I.1.4 (Not funded by GOAPP)

ZY Wang (Tang) – Project II.3.1 focuses on actual application of data assimilation, i.e., the assimilation of sea surface temperature into a realistic ocean model.

PhD Students: 8

J. Belanger (Berg) Project II.3.4. J. Belanger is working on the development of the soil moisture data sets which will be used in these evaluations.

S. Donohue (Stacey) Project I.1.4. This PhD candidate at RMC is running POP for the North Pacific, and although he is not directly involved in this project, he has benefited from discussions with Dr Shao, and vice versa. He is modelling the North Pacific, so there is obvious benefit to him that this project is occurring at RMC.

S. Higginson (Thompson) – Projects I.1.2 and I.1.3. (Not funded by GOAPP)

F. Lienart (Fyfe) – Project II.1.2. F. Lienart is now in the second year of his PhD program at the University of Victoria. He has assembled observational data and output from most of the World's global climate models and has completed a detailed intercomparison.

E. Oliver (Thompson) – Projects I.1.2 and I.1.3. (Not funded by GOAPP)

S. Rattan (Myers) – Project I.1.5. His work included the implementation of NATL4 configuration on Westgrid computers, the study of sea-ice representation in this configuration, as well as the impacts of oceanic assimilation and sub-grid scale parameterization on sea-ice fields. Also, he worked on the links between water formation in the eastern gyre and the Labrador Sea (presently being written up for publication). Sanjay successfully defended his thesis April, 2008 and is presently working as a post-doc at Florida State University.

M. Turnbull (Myers) – Project I.1.5. Her work included sea-ice data assimilation and the development of perturbed forcing and application to ensemble simulations to allow study of error correlations. She will be carrying out analysis of oceanic sea ice data assimilation and its impacts in the future.

X. Zhang (Thompson) - Projects I.1.2 and I.1.3. (Not funded by GOAPP). He is a visiting student from Nanjing University studying the tropical response of the Pacific to the MJO.

Post Doctoral Fellows: 8

F. Bakalian (Ritchie) – Project I.2.2. He is working in close cooperation with the co-investigators and collaborators.

Finnis, Joel (Hsieh) – Project II.3.3. Started June 1, 2008. He will be developing better ways to post process global coupled model forecasts.

Y. Liu (Thompson) – Projects I.1.2 and I.1.3. He is expanding his expertise in data assimilation while working on the projects.

Ajayamohan R.S. (Merryfield) – Project II.2.1. He is integrally involved in the partial coupling investigation reported under II.2.1 and will be contributing similarly to II.2.2 investigations.

J. Zhu (Demirov) – Projects I.1.4. He was involved in the development of NEMO ocean model for the North Atlantic and model hindcast experiments.

Research Associates: 6

G. Drewitt (Berg) Project II.3.4. He will be central to the development of the forcing data sets and offline land surface model simulations.

F. Dupont (Wright) – Project I.1.4. He is an expert in oceanography and computational methods. He is heavily involved in NEMO model development. He has become the unofficial "keeper of the NEMO code".

W-S Lee (Boer) – Project II.3.2. Dr, Lee is running coupled forecasts, managing and interpreting output and contributing to science.

Y. Shao (Stacey) – Project I.1.4. He is an expert in computational physics, and he does most of the simulations involving NEMO. He is heavily involved in model development and has become a very important member of the group.

S. Skachko (Gauthier) – Project I.2.1. Dr. Skachko is working on the development of the coupled atmosphere-ocean data assimilation, in close collaboration with colleagues from Environment Canada and from other GOAPP projects under Theme I.

T. Wakamatsu (Foreman) – Projects I.1.2, I.1.3, I.1.4. He is an expert in data assimilation. (Partially funded by GOAPP)

Z. Wang (Wright) – Project I.1.4. Dr. Wang was a research associate within the Center for Marine Environmental Prediction at Dalhousie University until January 2008 at which time he accepted a term position as a physical scientist with the Department of Fisheries and Oceans. He has again spent more than 50% of his time on GOAPP-related work with support from other funding sources (COMDA, Search and Rescue New Initiatives Fund (SAR-NIF), CSA), and he continues to increase his expertise with the NEMO code; he is a very valuable member of the COMDA-CONCEPTS-GOAPP research team. He will continue to spend significant time on the GOAPP project over the coming year.

See Appendix B for a diagram which shows the distribution of GOAPP participants.

5 OTHER

5.1 HOW COULD CFCAS ENHANCE ITS SUPPORT FOR UNIVERSITY-BASED RESEARCH IN CLIMATE AND ATMOSPHERIC SCIENCES, OR OTHERWISE ASSIST THE COMMUNITY? PROVIDE ANY REMARKS OR ADDITIONAL SUGGESTIONS FOR CFCAS.

Network participants are pleased with CFCAS support and are enthusiastic about the CFCAS commitment to distribute funds to supplement existing grant networks. Funding of our supplementary project proposal which is titled "Transitioning GOAPP Research to Operations: Real-time Data Assimilation and Forecast Systems" would be the best way to enhance support and to assist with the transfer of advances to the longer term government-led CONCEPTS initiative.

Appendix A
Acronyms and Abbreviations

Acronym/Abbreviation	Explanation
ACEnet	Atlantic Computational Excellence Network. ACEnet is Atlantic Canada's entry into this national fabric of high-performance computing facilities.
AGCM	Atmospheric General Circulation Model
AGRIF	Adaptive Grid Refinement In Fortran
AO	Atmosphere-Ocean
BIO	Bedford Institute of Oceanography
CaPA	Canadian Precipitation Analysis project
CCCma	Canadian Centre for Climate Modelling and Analysis
CGCM3 and CGCM4	Coupled Global Climate Model
CHFP	Coupled Historical Forecast Project (1, 2 and so forth)
CLASS	Canadian Land Surface Scheme
CLIVAR	An international research programme investigating climate variability and predictability
COMDA	Center of Ocean Model Development and Analysis
CONCEPTS	Coupled Environmental PredicTion Systems
CSA	Canadian Space Agency
DFO	Fisheries and Oceans Canada
DRAKKAR	Multi-scale Ocean Modelling Project http://www.ifremer.fr/lpo/drakkar/index.htm
EC	Environment Canada
DRI	Drought Research Initiative
ECMWF	European Centre for Medium-Range Weather Forecasts
EKF	Extended Kalman filter (EKF)
EnKF	Ensemble Kalman filter (EnKF)
ENSO	El Niño-Southern Oscillation
EOF	Empirical Orthogonal Functions
GEM	Global Environmental Multiscale Model
GEOIDE	GEOIDE's mission is to consolidate and strengthen the domestic geomatics industry, while making optimum use of Canada's Research and Development resources and to create a sustainable networking structure integrating all sectors of the Canadian geomatics community.
GHG	Greenhouse Gas
GOAPP	Global Ocean-Atmosphere Prediction and Predictability
GRACE	Gravity Recovery and Climate Experiment
HFP2	Historical Forecast Project 2
HPCVL	High Performance Computing Virtual Laboratory
IOS	Institute of Ocean Science

IPCC	Intergovernmental Panel on Climate Change
MI	Mutual Information
MSST	Mean Sea Surface Topography
MUN	Memorial University
NCEP	National Centers for Environmental Prediction
NEMO	Nucleus for European Modelling of the Ocean http://www.lodyc.jussieu.fr/NEMO/
NSERC	Natural Science and Engineering Research Council of Canada
NOCS	National Oceanographic Centre Southampton
OASIS	Ocean Atmosphere Sea Ice Soil - Ocean-atmosphere general circulation model coupler.
OGCM	Oceanic General Circulation Model
OPA	Another name for the NEMO model
QBO	Quasi-Biennial Oscillation
PDF	Post Doctoral Fellow
PI	Predictive Information
POP	Parallel Ocean Program
PP	Predictive Power (PP)
RA	Redundancy Analysis
RMC	Royal Military College
SAR-NIF	Search and Rescue New Initiatives Fund
SEEK filter	Singular Evolutive Extended Kalman filter
SGCM	Simplified General Circulation Model
SLP	Sea Level Pressure
SPKF	Sigma-Point Kalman filter
SST	Sea Surface Temperature
TL	Tangent Linear
UVic	University of Victoria
WestGrid	Collaborative project providing high-performance computing and multimedia/visualization resources to researchers and educators across Western Canada.
WCRP	World Climate Research Programme
WGSIP	Working Group on Seasonal to Interannual Prediction

Appendix B – Lists and Diagrams

Co-Investigators

Name	Affiliation
A. Berg	University of Guelph
G. Boer	University of Victoria
E. Demirov	Memorial University
J. Derome	McGill University
G. Flato	University of Victoria
J. Fyfe	University of Victoria
P. Gauthier	Université du Québec à Montréal
W. Merryfield	University of Victoria
P. Meyers	University of Alberta
M. Foreman	University of Victoria
H. Ritchie	Dalhousie University
J. Sheng	Dalhousie University
M. Stacey	Royal Military College
Y. Tang	University of Northern British Columbia
K. Thompson	Dalhousie University
W. Hsieh	University of British Columbia
D. Wright	Dalhousie University

Scientific Steering Committee

Co-Investigators	Affiliation
G. Boer	University of Victoria
J. Derome	McGill University
G. Flato (July 2007 to March 2008)	University of Victoria
M. Foreman (February 2008 onward)	University of Victoria
W. Merryfield (March 2008 onward)	University of Victoria
H. Ritchie	Dalhousie University
K. Thompson	Dalhousie University
D. Wright (July 2007 to February 2008)	Dalhousie University
S. Woodbury (ex-officio)	Dalhousie University

Appendix B

GOAPP Collaborators

Name	Affiliation
B. Archambault	Environment Canada
V. Arora	Environment Canada
S. Bélair	Environment Canada
M. Buehner	Environment Canada
G. Brunet	Environment Canada
T. Carrieres	Environment Canada
S. Kharin	Environment Canada
H. Lin	Environment Canada
Y. Lu	Environment Canada
A. Monahan	University of Victoria
T. Murdock	Pacific Climate Impact Consortium, University of Victoria
P. Pellerin	Environment Canada
F. Saucier	Université du Québec à Rimouski
J. Scinocca	Environment Canada
A. Shabbar	Environment Canada
A-M Treguier	Laboratoire de Physique des Océans, Brest, France
M-F Turcotte	Environment Canada
I. Yashayaev	Fisheries and Oceans Canada
B. Yu	Environment Canada

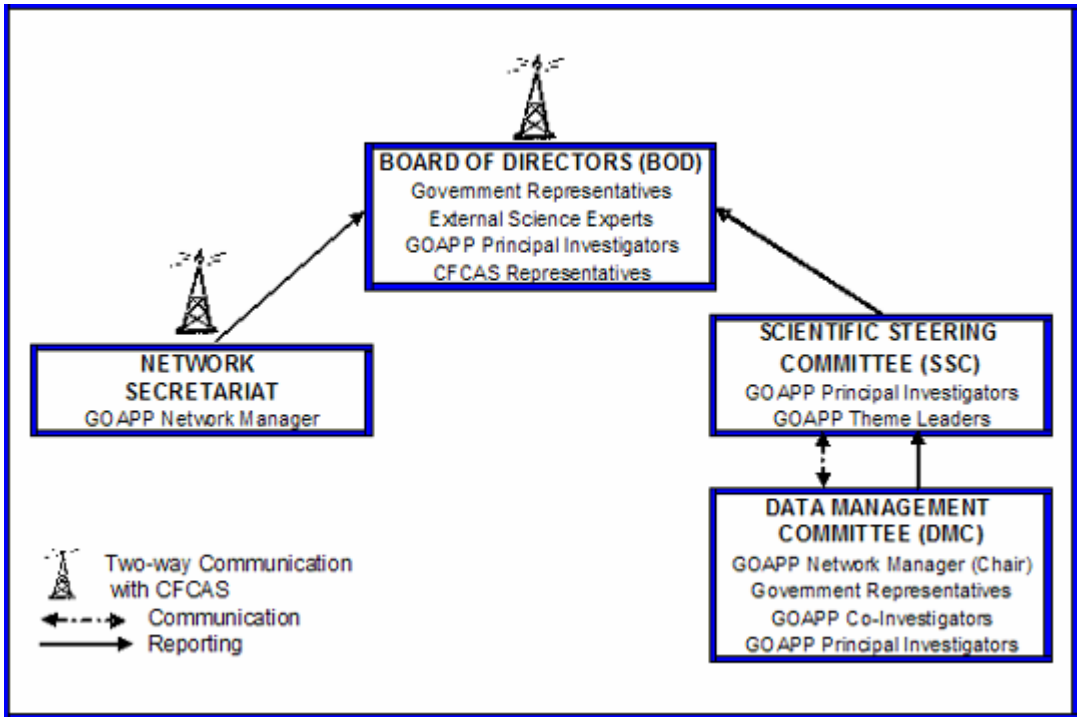
Appendix B

Board of Directors

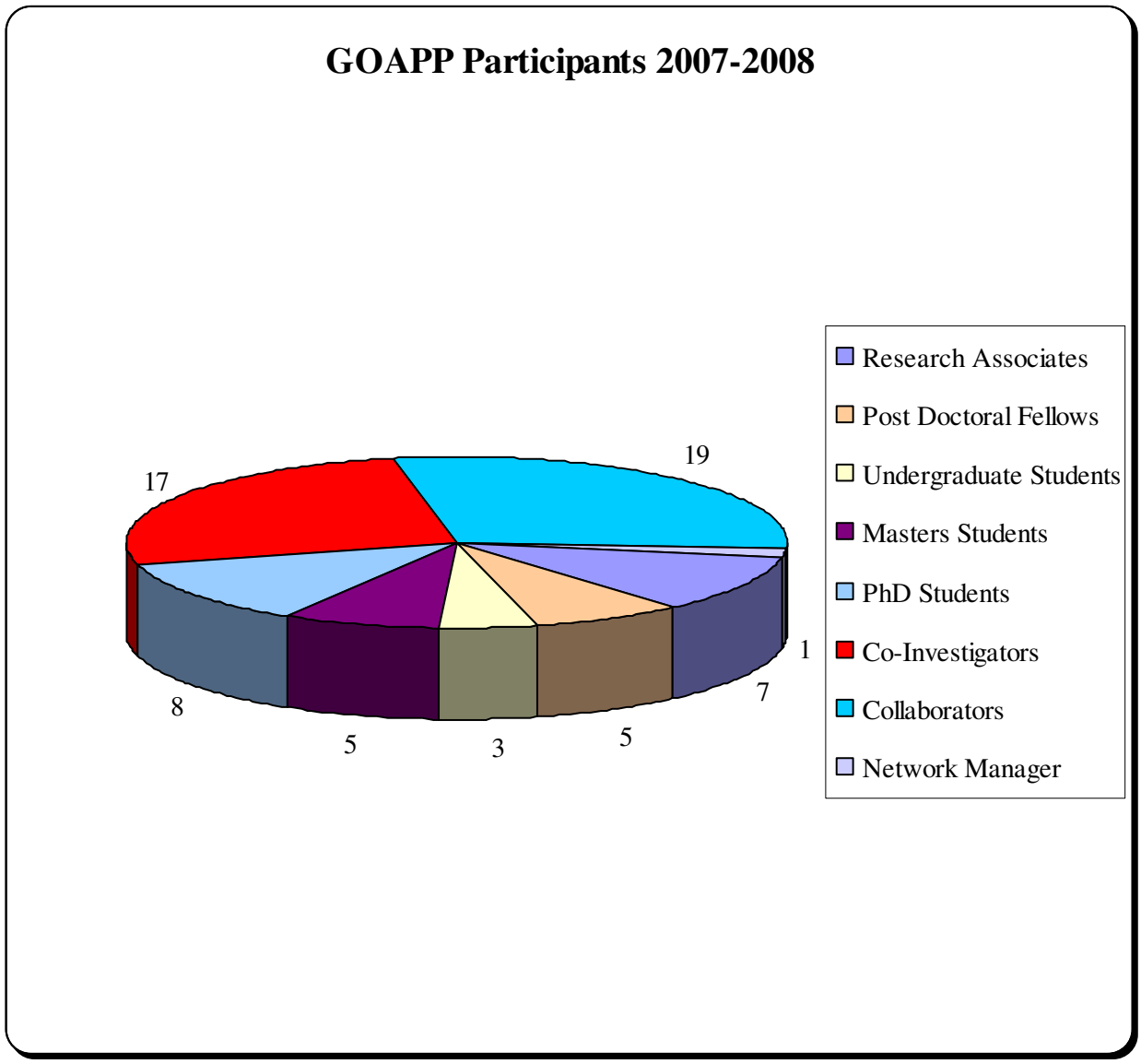
Name	Affiliation
M. Anderson	Department of National Defence
T. Aston (ex-officio)	Canadian Foundation for Climate and Atmospheric Sciences
A. Clarke	Fisheries and Oceans Canada
E. Dombrowsky	MERCATOR OCEAN
B. Kirtman	Rosenstiel School of Marine and Atmospheric Science
C. Lin	Environment Canada
S. Narayanan	Fisheries and Oceans Canada
H. Ritchie	Dalhousie University
K. Thompson	Dalhousie University
E. Wilson (ex-officio)	Canadian Foundation for Climate and Atmospheric Sciences
S. Woodbury (ex-officio)	Dalhousie University

APPENDIX B

GOAPP Management Structure



Appendix B


GOAPP Participants 2007-2008
19
17
1
7
8
5
3
5
Research Associates
Post Doctoral Fellows
Undergraduate Students
Masters Students
PhD Students
Co-Investigators
Collaborators
Network Manager

Appendix B

Highly Qualified Personnel

Name	Position	Affiliation
Ajayamohan R.S.	Post Doctoral Fellow	University of Victoria
J.T. Ambadan	Master's Student	University of Northern British Columbia
H. Ashworth	Undergraduate Student	University of Guelph
Faez Bakalian	Post Doctoral Fellow	Dalhousie University
J. Belanger	PhD Student	University of Guelph
Jorge Urrego Blanco	Master's Student	Dalhousie University
L. Courtney	Master's Student	University of Guelph
Shawn Donohue	PhD Student	Royal Military College
Frederic Dupont	Research Associate	Dalhousie University
Gordon Drewitt	Research Associate	University of Guelph
Joel Finnis	Post Doctoral Fellow	University of British Columbia
Madlena Hakobyan	Master's Student	Memorial University
Simon Higginson	PhD Student	Dalhousie University
Woo-Sung Lee	Research Associate	University of Victoria
Fabian Lienart	PhD Student	University of Victoria
Yimin Liu	Post Doctoral Fellow	Dalhousie University
Khoa Nguyen	Undergraduate Student	University of Alberta
Eric Oliver	PhD Student	Dalhousie University
Sanjay Rattan	PhD Student	University of Alberta
Yunfeng Shao	Research Associate	Royal Military College
Sergey Skachko	Research Associate	Université du Québec à Montréal
Mattea Turnbull	PhD Student	University of Alberta
Tsuyoshi Wakamatsu	Research Associate	University of Victoria and DFO
ZhiYu Wang	Master's Student	University of Northern British Columbia
Zeliang Wang	Research Associate	DFO (BIO)
N. Wu	Undergraduate Student	University of Victoria
Xu Zhang	PhD Student	Dalhousie University
Jieshun Zhu	Post Doctoral Fellow	Memorial University

Appendix B

GOAPP Workshop May 25, 2008

Back Row: Ron Stewart, Tim Aston, Shawn Donohue, Mike Stacey, Aaron Berg, Keith Thompson, Yunfeng Shao, Fred Dupont, Gordon Drewitt, Fabian Lienart, Entcho Demirov, Zeliang Wang, Eric Oliver, Youyu Lu

Middle Row: Erica Wilson, Yimin Liu, Slava Kharin, Bill Merryfield, Ajayamohan R.S., Paul Myers, Faez Bakalian, Tsuyoshi Wakamatsu, William Hsieh, Hai Lin

Front Row: Hal Ritchie, Jacques Derome, Dan Wright, Susan Woodbury, George Boer, Youmin Tang
Missing: Dawn Conway

Appendix C

Workshop on the CFCAS-funded Research Network
Global Ocean Atmosphere Prediction and Predictability (GOAPP)

Sunday, 25 May 2008, Kelowna, BC
The Grand Okanagan Hotel – Vaseaux Meeting Room

Purpose: Review progress[1], describe new projects, identify problems and opportunities for new research, encourage collaboration, discuss information management and sharing, review network structure.

0845	Welcome, Logistics and Introductions (by participants)	Keith Thompson, Hal Ritchie, CFCAS Rep., Susan Woodbury
0915	Review and Discussion of Theme I.1 (Ocean Data Assimilation and Sea Ice Modelling) 5 projects	Dan Wright
1015	***Health Break***	
1030	Review and Discussion of Theme I.2 (Coupled modeling and assimilation, global model configurations, ...) 2 projects and CFCAS supplement	Hal Ritchie
1100	Review and Discussion of Theme II (Analysis and mechanisms, predictability, coupled model initialization and forecast, forecast post-processing and verification)	Bill Merryfield
1200	Review and Discussion of Theme II (Continued)	Slava Kharin
1215	Review and Discussion of Theme II (Continued)	Youmin Tang
1230	***Lunch Break (Provided)***	
1330	Review of New Project: Seasonal Climate Forecasts and Land Surface Processes; GOAPP interaction with the CFCAS-funded DRI Research Network	Aaron Berg
1350	Review of New Project: Shelf Downscaling	Keith Thompson for J. Sheng
1410	Presentation of Upcoming Project: Forecast Combination, Calibration and Verification	William Hsieh
1430	Open discussion of research gaps, issues and opportunities for collaboration	George Boer
1500	***Health Break***	
1515	Use of Unspent Funds	Susan Woodbury

[1] Nineteen oral presentations by GOAPP researchers will be given in three blocks during the congress. There will be three poster presentations as well.

1520	Facilitating Collaboration (funding travel of HQP)	Keith Thompson
1545	Information Management (status of data management, GOAPP website, GOAPP data server)	Bill Merryfield Susan Woodbury
1600	GOAPP management: SSC and rotation of membership, reports on Science Day and Board of Directors' meeting.	Hal Ritchie
1615	Annual Report and spending of funds in the final year	Susan Woodbury
1645	Wrap up	Hal Ritchie

LIST OF PARTICIPANTS

Ajayamohan R.S.	GOAPP Post Doc
Tim Aston	CFCAS
Faez Bakalian	GOAPP Post Doc
Aaron Berg	GOAPP Co-Investigator
George Boer	GOAPP Co-Investigator
Dawn Conway	CFCAS
Entcho Demirov	GOAPP Co-Investigator
Jacques Derome	GOAPP Co-Investigator
Shawn Donohue	GOAPP PhD Student
Gordon Drewitt	GOAPP Research Associate
Frederic Dupont	GOAPP Research Associate
Slava Kharin	GOAPP Collaborator
William Hsieh	GOAPP Co-Investigator
Fabian Lienart	GOAPP PhD Student
Hai Lin	GOAPP Collaborator
Yimin Liu	GOAPP Post Doc
Youyu Lu	GOAPP Collaborator
Bill Merryfield	GOAPP Co-Investigator
Paul Myers	GOAPP Co-Investigator
Eric Oliver	Dalhousie Master's Student
Hal Ritchie	GOAPP Principal Investigator
Yunfeng Shao	GOAPP Research Associate
Mike Stacey	GOAPP Co-Investigator
Ron Stewart	DRI Network Principal Investigator
Youmin Tang	GOAPP Co-Investigator
Keith Thompson	GOAPP Principal Investigator
Tsuyoshi Wakamatsu	GOAPP Post Doc
Zeliang Wang	GOAPP Research Associate
Erica Wilson	CFCAS
Susan Woodbury	GOAPP Network Manager
Dan Wright	GOAPP Co-Investigator

CMOS 2008 schedule for "Global coupled models" ~ "Global Coupled Atmosphere-Ocean Modelling and Assimilation"

Wed. May 28 3B5 10:30 – 12:00 6 oral

Assimilation of Data into Ocean Models: On-Line Estimation of Background Error Covariance Parameters
Keith Thompson, *Yimin Liu*

Data assimilation in a regional ocean model of the Labrador Sea
Entcho Demirov, *Jieshun Zhu*, *Madlena Hakobyan*

Initialization of Coupled Seasonal Forecasts by Assimilation of an Ensemble of Ocean Reanalyses
Woo-sung Lee, *William J. Merryfield*, *Youmin Tang*

The inverse modeling of the seasonal variation of the Eastern North Pacific Ocean circulation
Tsuyoshi Wakamatsu, *Mike Foreman*, *Keith Thompson*

Advanced Data Assimilation in Strongly Nonlinear Systems via Sigma-point Kalman Filters.
Jaison Thomas Ambadan, *Youmin Tang* University of Northern British Columbia

Connections Between the Madden Julian Oscillation and Extratropical Regions of the Global Ocean and Atmosphere
Eric Oliver, *Keith Thompson*

Wed. May 28 3C5 13:30 – 15:30 8 oral

Changes in the decadal-scale potential predictability of the coupled system with global warming
G.J. Boer Canadian Centre for Climate Modelling and Analysis

Improving seasonal forecast skill in Canada using a post-processing method
Xiaojing Jia, *Hai Lin*, *Jacques Derome*

North Pacific Sea Surface Temperature Climatology and Variability in the World's Global Climate Models
Fabian Lienert, *John C. Fyfe*

Decadal/Interdecadal variations in ENSO predictability in a hybrid coupled model from 1881-2000
Ziwang Deng, *Youmin Tang*

The Singular Vector (SV) Analysis of An ENSO Prediction Model For The Period From 1856-2003
Yanjie Cheng, *Youmin Tang*, *Xiaobing Zhou*

Regional and Global Scale Redundancy Analyses of the Coupled Atmosphere-Ocean System
Faez Bakalian, *Harold Ritchie*, *Keith Thompson*, *William Merryfield*

Regional influences of ocean-atmosphere interaction on climate variability assessed using partial coupling
Ajayamohan Ravindran, *William Merryfield*

Wed. May 28 3D 16:00 – 17:30 Posters

Towards sea ice assimilation in NEMO: Background Error Covariances
Mattea Turnbull, *Paul Myers*

Simulating the Northeast Pacific Ocean using OPA
Yunfeng Shao, *Michael W. Stacey*

Comparison of precipitation fields over Canada estimated from reanalysis products.
Gordon Drewitt, *Berg Aaron*

Thurs. May 29 4B5 10:30 – 12:45 6 oral

Recent developments for an operational Canadian global assimilation and prediction capability for the coupled atmosphere-ocean-ice system
C. Harold Ritchie, *Fraser Davidson*, *John Loder*, *Youyu Lu*, *Pierre Pellerin*, *Wayne Renaud*, *Marty Taillefer*, *Keith Thompson*, *Dan Wright*

Initial assessment of the CONCEPTS global 1/4-deg ocean and sea-ice model
Youyu Lu, *Jean-marc Belanger*, *Francois Roy*, *Hal Ritchie*, *Dan Wright*, *Zeliang Wang*, *Frederic Dupont*, *Greg Holloway*, *Gilles Garric*

Progress in Modelling Gulf Stream Separation with an Eddy Admitting Model
D.G. Wright, *Z. Wang*, *F. Dupont*, *K. Thompson*, *Y. Lu*

The effects of eddy parameterization in a coarse-resolution global ocean and sea-ice model
Zeliang Wang, *Dan. Wright*, *Youyu Lu*, *Greg Holloway*, *Fred Dupont*

Sensitivity study of the North Atlantic circulation. What are the optimal parameters or parameterizations in NEMO?
Frederic Dupont, *Dan Wright*, *Zeliang Wang*, *Keith Thompson*

Rossby Waves and the North Pacific Current
Shawn M. Donohue, *Michael W. Stacey*, *Jennifer A. Shore* Royal Military College of Canada

Appendix D - GOAPP Science Day

Thursday, February 28, 2008
The Cambridge Suites Hotel, Halifax, Nova Scotia
AGENDA

0845	Welcome and Logistics	Allyn Clarke, Erica Wilson, Hal Ritchie, Keith Thompson, Susan Woodbury
0900	Overview Theme 1	Hal Ritchie
0920	Overview Theme II	Bill Merryfield
1000	***Refreshment Break***	
1020	Theme I projects I.1.1 and I.1.4	Dan Wright
1040	Theme I projects I.1.2 and I.1.3	Keith Thompson
1100	Theme I project I.2.1	Pierre Gauthier
1120	Theme I projects I.2.2 and I.1.5	Hal Ritchie
1140	Discussion	
1200	***Lunch (Provided by GOAPP)***	
1300	Overview Presentation on Mercator Activities	Eric Dombrowsky
1340	Discussion	
1350	Progress report on coupled seasonal forecasting at CCCma	Bill Merryfield
1420	Redundancy Analyses of the Coupled Atmosphere-Ocean System for Global and Regional Scales	Faez Bakalian (PDF)
1435	Optimized Parameters and Updated Code	Fred Dupont (Research Associate)
1445	Online Bias Correction and Background Error Covariance Estimation for Ocean Models	Yimin Liu (Research Associate)
1500	Climatologies Based on De-Eddied Profile Data	Simon Higginson (PhD)
1510	Extra Tropical Expressions of the MJO	Eric Oliver (PhD)
1520	***Refreshment Break***	
1530	Discussion (with input from CFCAS) - CONCEPTS - Research to Operations (GOAPP Supplement)	 Hal Ritchie/Brenda Topliss Keith Thompson
1630	Adjournment	