GOVERNMENT OF CANADA PROGRAM FOR INTERNATIONAL POLAR YEAR (IPY)
2007/08 PROGRESS REPORT

Project Title: **TAWEPI** - Thorpex Arctic Weather and Environmental Prediction Initiative	
Government of Canada Project Number: 2006-SR1-CC-088	**IPY International Project Number(s):** 638
Project Website (if available): http://collaboration.cmc.ec.gc.ca/science/rpn/tawepi/en/index.html	

Principal Investigator

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Project Team

Please complete this information for each member of your project team (this may include co-applicants, collaborators and other key contributors such as Elders and students). Add additional rows as necessary.

Name	Affiliation	Role (i.e., Co-applicant, Collaborator, Other key contributor, e.g. graduate student, Elder, technician etc.)	Contact Information
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1. Plain Language Summary

Provide a plain language summary of the project, including essential background information, purpose of the project, a description of the progress to date, key activities and early results. This summary will be made available to the public and should be written at a level appropriate for a popular magazine or newspaper. (500 words maximum)

Weather and Environmental Prediction (WEP) constitutes one of the most important technological and societal successes of the last century. The positive impact of WEP on health, safety and economic competitiveness is recognized worldwide. The benefit of WEP applications in polar regions has been somewhat delayed due the higher priority of forecasting in the more densely populated southern regions. Concerns about an amplification of anthropogenic climate change at higher latitudes combined with an increasing interest of the federal Government in exerting Canadian sovereignty throughout the Arctic requires a better understanding of weather and climate processes in this region so as to improve our ability to make reliable, quantitative predictions. The International Polar Year provides the important international context for a Canadian-led initiative to improve WEP capabilities for the Arctic.

The primary objective of TAWEPI is to develop and validate a regional Numerical Weather Prediction (NWP) model over the Arctic during the IPY observational period. The proposed experimental model, called Polar-GEM, will be a twin of the Environment Canada (EC) operational regional GEM (Global Environmental Multiscale) model, used for one- to two-day weather forecasts. This initiative includes modelling research and data assimilation studies that will help enhance our weather and environmental forecasting capabilities in Polar Regions and improve our understanding of the Arctic and its influence on world weather. These research activities and studies are taking place in various research divisions of EC, in collaboration with the Canadian Meteorological Centre (CMC), the Canadian Ice Service (CIS), the Department of Fisheries and Oceans (DFO), various Canadian universities and other IPY projects.

TAWEPI's research activities started in April 2007 and the first steps in the development of the Polar-GEM model have been taken. A research version of the model, covering the Arctic basin and surrounding regions has been proposed. A state-of-the-science sea-ice model is being adjusted to improve the sea-ice representation in the domain of the Polar-GEM. High-resolution sea-ice concentration analyses have recently become available and are being tested in the framework of the Polar-GEM system. A multi-layer snow model, describing processes over the various types of surfaces of the Arctic environment, such as sea-ice, tundra, glaciers and ice caps, is currently being implemented in Polar-GEM. Using a stratospheric extension of the GEM model, preliminary analyses of the stratosphere are being generated for the IPY period, including estimates of the ozone field, which will lead to an improved understanding of polar processes in the atmosphere.

2. Key Messages

Please provide plain language key messages in bullet form, which would key progress and/or results thus far. (Maximum of 3 to 5 key messages)

- Project S1.1 – Snow processes in Polar-GEM:

Preliminary steps for implementation of a multi-layer snow model (SNTHERM) in the Polar-GEM model have been taken; some technical problems have been overcome and sensitivity tests are currently in progress.

- Project S2.1 – Sensitivity studies for weather forecast in the Arctic:

An algorithm designed to identify sensitive regions for weather forecast was adapted for the Artic region; calculations for the summer and fall 2007 have started and will continue through the entire IPY period.

- Project S2.3 – Stratospheric analyses during IPY:

A configuration of the data assimilation system with chemistry has been chosen and the generation of a time series of stratospheric analysis for the first period (2007/2008) of IPY has begun.

- Project S3 – Sea-ice model development:

A "state-of-the-science" sea-ice model (version 3.14 of the Los Alamos Community Ice CodE - CICE) has been downloaded and adjusted for simulations at the Canadian Centre for Climate modelling and analyses (CCCma) facilities; preliminary tests show promising results.

3. Introduction

This introduction to the project should briefly cover the rationale, overall project purpose and objectives, as well as linkages to other projects in Canada and internationally.

In a significantly changing Arctic climate it will be more and more difficult to rely on traditional and climatological knowledge to predict day-to-day to seasonal environmental variability. Indeed, experienced elders and hunters who have been able to predict the weather for most of their lives are finding that recently their prediction skills no longer work and the weather changes they are witnessing are unprecedented. It will be essential to rely on science based forecasting technologies to reduce the impact of weather and related hazards on health, safety and the economy.

The primary objective of TAWEPI is to develop and validate a regional Numerical Weather Prediction (NWP) model over the Arctic during the IPY observational period. The proposed experimental model, called Polar-GEM, will be a twin of the Environment Canada operational regional GEM (Global Environmental Multiscale) model, used for one- to two-day weather forecasts. This initiative includes modelling research and data assimilation studies that will help enhance our weather and environmental forecasting capabilities in Polar Regions and improve our understanding of the Arctic and its influence on world weather.

TAWEPI is a component the International IPY-THORPEX initiative. THORPEX is an international research and development program, created in response to weather related challenges of the 21st century, and aiming to accelerate improvements in the accuracy of 1-day to 2-week high-impact weather forecasts, for the benefit of society, the economy and the environment. THORPEX research topics include: global-to-regional influences on the evolution and predictability of weather systems; global observing system design and demonstration; targeting and assimilation of observations; societal, economic and environmental benefits of improved forecasts.

The development of the Polar-GEM model is planned to take place in collaboration with the Canadian Meteorological Centre (CMC). The development and coupling of the sea-ice model will be done through cooperation among EC, CIS and DFO. Various TAWEPI investigators are members or collaborators of other national and international IPY projects and programs, such as THORPEX-IPY, ArcticNet, the "Circumpolar Flaw Lead" (CFL) project, SPARC-IPY, and the project "Variability and Change in the Canadian Cryosphere".

4. Activities and Progress in 2007

Please identify the regions in which the activities described below took place:

☐ Yukon ☐ Nunavik
☐ Northwest Territories ☐ Nunatsiavut
☐ Nunavut ☒ Other: Quebec, Ontario, British Columbia

a) Please provide details about the project's progress towards meeting its goals, and include information about where and when activities took place.

TAWEPI's research activities were planned as five PDF and one RA projects, taking place in three EC centres (in Dorval, Downsview and Victoria) dedicated to numerical weather prediction, data assimilation and climate modelling/diagnostics.

Due to delays in the approval of funds, in the selection process, and in visa related issues, some PDFs arrived later than the planned starting date (April 2007): while two PDFs did start in the spring 2007, one started later in the summer, one in the fall, and two will start in 2008 only. Some details about the progress made so far are provided below (each subproject is discussed separately).

S1.1 - Snow processes in Polar-GEM
The multi-layer SNTHERM snow model has been tested to predict snow evolution forced by measurements at the Surface Heat Budget of the Arctic Ocean (SHEBA) from October 1997 to October 1998. A sensitivity study shows that snow evolution was sensitive to surface albedo, new snow density, threshold temperature for precipitation types, and solar extinction.

S1.2 – Arctic clouds
To start in March 2008.

S2.1 - Sensitivity studies for weather forecast in the Arctic
In this initial phase of the project, a configuration of the singular vector algorithm (model configuration, optimization time, initial and final time norms) was chosen to study the sensitivity of the Arctic weather to disturbances originated elsewhere. Calculations for the summer and fall 2007 have started and will continue through the entire IPY period. The climatology, and other statistical and physical properties of these sensitive regions for the duration of IPY, will be generated and archived.

S2.2 – Validation and assimilation of satellite data from polar orbiting satellites
To start in January 2008.

S2.3 - Stratospheric analysis during IPY
A configuration (3D-FGAT) of the data assimilation system with chemistry has been chosen and the generation of a time series of stratospheric analysis for the first period (2007/2008) of IPY has begun.

S3 - Sea-ice model development
Version 3.14 of the Los Alamos Community Ice CodE (CICE) has been downloaded to CCCma machines, together with documentations and an atmospheric forcing data set (1997) for testing purposes. The model setup has been adjusted to allow the model to compile and run on the CCCma AIX machines (Addition of Macros.AIX.CCCma.ax and editing comp_ice, clean_ice). The model has been executed for one month with the provided test forcing data set and shows reasonable results. The model compilation file has then been extended to link CCCma model libraries. (Note that problems arose because of the compiler option -qextname / -qnoextname. The model is now compiled using FFLAGS -qextname, consequently the netcdf directory needed to be changed to /usr/local/netcdf-3.5.1-qext). As a first application of the linked CCCma libraries, the resulting ice fields have been printed out in CCCma format. This will now gradually be extended to read in CCCma-files and finally run the model on the CCCma grid.

b) Describe how the IPY Northern Coordination Offices have assisted in the planning, coordination and/or delivery of any aspect of the project.

Not needed so far.

5. Issues and Challenges

Discuss any problems encountered, how they have been addressed and any resulting deviations from the original approved application.

The original scenario for Polar-GEM was planned as an extension of the current operational regional GEM model to cover the Arctic. This scenario that could eventually replace the operational regional configuration is currently being investigated by CMC. It requires significant new funding for its development and, so far, the needed funding has not been obtained by CMC. Therefore, an alternative scenario with a research version of Polar-GEM has been proposed in which the model domain is limited to the Arctic basin and surrounding regions. The proposed activities have begun based on this research version of Polar-GEM.

S1.1 - Snow processes in Polar-GEM
The multi-layer snow model (SNTHERM) that is currently being implemented in Polar-GEM is rather computationally expensive. It was found that the snow model is particularly inefficient for grid points with very little or no snow. The problem was solved by restricting SNTHERM calculations to grid points with snow.

S1.2 – Arctic clouds
To start in March 2008.

S2.1 - Sensitivity studies for weather forecast in the Arctic
Initial calculations of singular vectors in the Arctic for the summer of 2007 indicated some limitations in disk space (archiving). The problem will be solved once more disks are purchased.

S2.2 – Validation and assimilation of satellite data from polar orbiting satellites
To start in January 2008.

S2.3 - Stratospheric analysis during IPY
The original GEM-BACH IPY analysis cycle was being run to provide full dynamic and chemical analyses of the stratosphere during IPY (March 2007 – March 2009). Since the 4D-Var system now runs slower that real-time, it was no longer possible to restart a 4D-cycle and have it completed in time for the end of IPY. An alternative setup has been identified, based on a 3D-Var cycle of the GEM-mesostrato model that is already being run.

S3 - Sea-ice model development
Because the funds came as O&M rather than G&C or directed to a University (as had initially been requested), there was some difficulty in hiring a qualified person to undertake this work. The initial stage of the project is highly technical, requiring someone with scientific expertise in sea-ice modelling as well as advanced computing skills. Such a person was identified early on but in the end, the only mechanism to hire her (temporarily) was via a contract. In the end the work proposed is being done (albeit somewhat behind schedule). A more sustainable solution is being sought for next year.

6. Results and Discussion

a) Describe any results to date and their significance/impact with respect to the science for climate change impacts and adaptation and/or the health and well being of northern communities. Please include figures and tables as appropriate.

S1.1 - Snow processes in Polar-GEM
Preliminary results show that the model precisely captures the start and end date of snow on the ground, but overestimates the snow depth. Pre-coupling results indicate that the thermal conduction from the sea ice model affects the vertical temperature stratification more significantly in the winter, especially in the lower snowpack. This conductive heat does not alter the simulated snow depth but causes an increase of 9.69 K (maximum) in snow temperature profiles.

S1.2 – Arctic clouds

To start in March 2008.

S2.1 - Sensitivity studies for weather forecast in the Arctic
Results are still preliminary but an increasingly robust picture of sensitive regions is expected to take shape as more cases are studied. This picture of the most sensitive regions will help design the most appropriate configuration of the regional NWP models (the Polar-GEM and the smaller, higher-resolution sub-domains). An example of Arctic regions whose weather forecast is sensitive to initial condition errors is shown in the figure below.

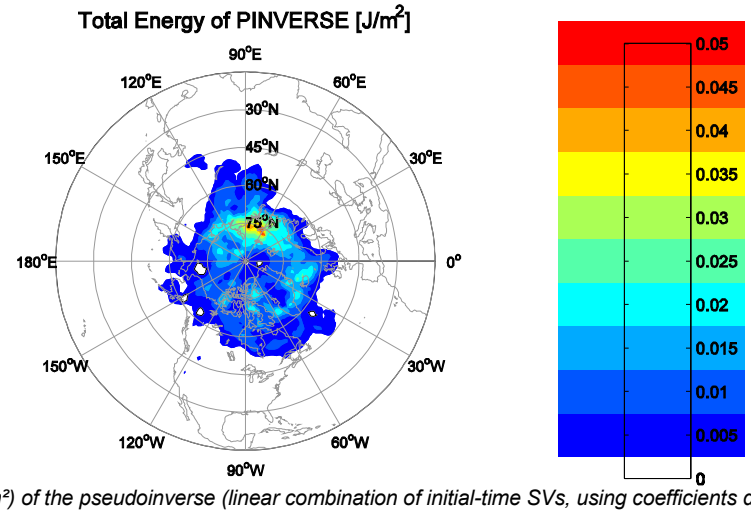

***Figure**: Total energy (J/m²) of the pseudoinverse (linear combination of initial-time SVs, using coefficients defined by the projection of the final-time SVs on forecast error) vertically integrated and averaged over the period 11-Jul to 11-Aug 2007. This average distribution shows sensitive regions, where unstable perturbations to initial conditions were likely to impact on the 48-h forecast over the Arctic during that period.*

S2.2 – Validation and assimilation of satellite data from polar orbiting satellites
To start in January 2008.

S2.3 - Stratospheric analysis during IPY
Various configurations of stratospheric analysis cycles have been tested and a number of supporting diagnostic tools were developed. An optimal configuration is under evaluation. The resulting analyses will be provided to the SPARC IPY database in a portable format. A subset of the results will be compressed and archived at the CMC. Aspects of the data set which have particular research value will be explored, and results will be described in a report.

S3 - Sea-ice model development
Results are preliminary so far, as the project has only just gotten underway. Initial work has laid the groundwork for future research by preparing the model code and getting it to run on EC computers.

b) Are you aware of ways in which the results of this research are going to be used by others? If so, please explain.

All modelling projects and data assimilation studies of TAWEPI are expected to contribute to the development of the Polar-GEM system. It is also expected that this experimental system could be developed in collaboration with the CMC, and will represent the main legacy of TAWEPI.

Results and data generated by TAWEPI will be archived (see description in section 7) and will be used by collaborators and students, during and beyond the IPY period.

c) Please list publications and posters/presentations given at conferences that are directly related to this project.

Zadra, A., 2007: "Modelling and data assimilation activities in TAWEPI"
Presentation given by A. Zadra at the 2007 Canadian Meteorological and Oceanographic Society Congress, session I13 (Coordination of Activities in the International Polar Year), St-John's, Newfoundland, May 2007

Zadra, A., 2007: "Modelling surface-atmosphere momentum exchanges"
Presentation given by A. Zadra at the 1st CFL Planning Meeting, Quebec City, March 2007

Chung, Y.-C., S. Belair and J. Mailhot, 2007: "Snow evolution over sea-ice during SHEBA using the SNTHERM snow model"
Poster presented by Y.-C. Chung at the American Geophysical Union (AGU) Conference, San Francisco, CA, USA, 10-14 December 2007

Saenko, O. A., A. J. Weaver, D. Y. Robitaille and G. M. Flato, 2007: Warming of the subpolar Atlantic triggered by freshwater discharge at the continental boundary. Geophysical Research Letters, 34, L15604, doi:10.1029/2007GL030674

7. Data Management

a) Briefly describe/list the data set(s) collected and or used during the current funding year.

Please note that for TAWEPI's activities, the term "data management" refers mostly to the generation and archiving of data generated by numerical models (e.g. weather forecasts, atmospheric analyses, climate simulations).

No observational data is collected in Arctic sites by activities funded by TAWEPI. According to clarifications provided by experts at the IPY Researchers Workshop (October 2007, Gatineau), the delicate data management / data policy issues discussed during the workshop do not apply to the type of data produced by the research activities in TAWEPI (i.e. numerical data generated or processed by our numerical models).

b) Briefly describe steps taken to-date and systems being used to manage and archive data and metadata, as well as the methods being employed to ensure quality (quality assurance/quality control). Also, describe future plans with regards to managing this project's data.

Most data and metadata generated by TAWEPI modelling activities will be archived at the CMC, as described in the original proposal.

Regarding subproject S2.3 (Stratospheric analysis during IPY): A copy of the stratospheric analyses will continue to be provided to the SPARC-IPY database.

Regarding subproject S3 (Sea-ice model development): The CCCma has a robust data storage system both locally (in Victoria) and at the EC supercomputing facility in Dorval. Some of the funds from this project have been used to upgrade the local data storage system in Victoria to allow a greater volume of model output to be held locally for analysis and for distribution to users via the CCCma web server. This data is held on a reliable RAID system, with tape back-ups locally and in Dorval.

c) Identify the project team member(s) responsible for managing the data for this project.

Jocelyn Mailhot (RPN/EC) is responsible for the development of the Polar-GEM model.

Louis Garand (ARMA/EC) is responsible for the data assimilation projects in TAWEPI.

Greg Flato, Manager of CCCma, is responsible for data management of the sea-ice project.

8. Training and Capacity-Building

a) Describe the education and training opportunities, both formal and informal, provided through this project, including the extent to which Northerners and Aboriginal people have benefited from these opportunities. Please indicate how many individuals were involved in each activity and the type of training provided.

Not applicable so far as the projects have just started, but this will change as the model and the data begin to be used by students and collaborators.

b) Students and New Researchers

Please provide information about the students and new researchers[1] who have participated in this project to date using the table below.

Note: Students and new researchers listed below may also be listed as project team members on page 1 of this report.

This information will be used by the IPY Federal Program Office to determine the level of involvement of students and new researchers in IPY projects and, at the completion of IPY, to assess whether these students continue in Northern research or other science fields beyond IPY. The data collected in this table will only be used by the IPY Federal Program Office and the Science Review Boards. No information that identifies an individual or which could be used to deduce the identity of an individual will be released to the public. Any statistical data derived from this information will only be released to the public in aggregate form. Provision of information marked with an asterisk (*) is voluntary. Under the *Privacy Act*, the individual to whom the information pertains has rights of access to, and protection of, the personal information provided.

Add additional rows as necessary.

Name*	Affiliation and contact information*	Current Education Level (e.g., High School, College, Undergraduate, Masters, PhD, PDF or N/A)	Northern student[2]	New Researcher	Nature of Involvement (Indicate the type of activity each individual undertook)	Time (indicate duration i.e. number of days, months)
Yi-Ching Chung	MRD / EC yi-ching.chung@ec.gc.ca	PDF		X	full-time investigator; implementation and testing of multi-layer snow model	since Aug 2007
Frederick Chosson	MRD / EC chosson@cerfacs.fr	PDF		X	full-time investigator	to start in Mar 2008
Ahmed Mahidjiba	MRD / EC ahmed.mahidjiba@ec.gc.ca	PDF		X	full-time investigator	since Apr 2007
Ovidiu Pancrati	MRD / EC ovidiu.pancrati@ec.gc.ca	PDF		X	full-time investigator	since Jan 2008
Mateusz Reszka	MRD / EC mateusz.reszka@ec.gc.ca	PDF		X	full-time investigator	since Apr 2007

[1] New researchers are individuals who are younger than 30 **OR** who have less than 10 years northern research experience.

[2] Northern students are individuals who originate from the North or whose permanent residence is in the North and who are enrolled in a formal education or training program. For the purposes of the IPY Program, the North is defined as the three Territories as well as the northern parts of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Newfoundland and Labrador.

Nadja Steiner	contractor CRD / EC nadja.steiner@ec.gc.ca	PhD		X	full-time investigator; sea-ice model implementation and testing	since Oct 2007

9. Northern Community Engagement

a) Describe how this project has engaged Northerners, northern communities and Aboriginal organizations (e.g., consultation, partnerships, membership on project team, outreach activities, etc.). In addition, please fill out the table below.

Not applicable so far.

This information will be used by the IPY Federal Program Office to determine the level of involvement of Northerners in IPY research projects. The data collected in this table will only be used by the IPY Federal Program Office and the Science Review Boards. No information that identifies an individual or which could be used to deduce the identity of an individual will be released to the public. Any statistical data derived from this information will only be released to the public in aggregate form. Provision of information marked with an asterisk (*) is voluntary. Under the *Privacy Act*, the individual to whom the information pertains has rights of access to, and protection of, the personal information provided.
Add additional rows as necessary.

Name* (if applicable)	**Community, Institution or Affiliation**	**Nature of Involvement** (indicate the type of activity each individual undertook)	**Time** (indicate duration i.e. days, months)

b) How id this project integrating Traditional Knowledge and western science?

Not applicable so far.

10. Communication and Outreach

Describe any communication and outreach activities and products developed to date, for example community consultations, presentations, websites, posters etc. Please provide copies of any communications materials developed.

Not applicable so far.

11. Upcoming Activities

Describe the work that will be carried out in the next fiscal year (April 1, 2008 to March 31, 2009) and any expected changes that will be made to the project as compared to the originally approved project proposal and any financial implications of these changes. Please complete Budget Table 1 using the template provided to you.

Due to the late arrival of some PDFs, some projects are slightly behind schedule. Some technical difficulties, as discussed in sections 5 and 6 of this report, demanded some adaptations in the research strategies. Otherwise, there are no major deviations from the original plans.

12. Revenue and Expenditures

a) Please complete the *2007/08 Statement of Revenue and Expenditures* using the template and worksheets that have been provided to you. The template and worksheets cover actual expenditures from April 1, 2007 to December 31, 2007 and projected expenditures from January 1, 2008 to March 31, 2008. (Note: A fiscal year-end Financial Report confirming total expenditures will be required by May 31, 2008)

Please see attached worksheets.

b) Explain any deviations from the previously approved budget and how you propose to address them.

Please note that Dr. Pierre Gauthier has recently left EC, and that Dr. Louis Garand (ARMA/MRD/EC) has kindly agreed to replace him as the principal investigator of TAWEPI's projects on data assimilation. This change has been approved by MRD/EC.

In the approved budget of TAWEPI, the IPY funds received for the first year (April 2007 to March 2008), that is $342,000 corresponding to the salary and travel expenses of six PDFs ($55,000 for salary and $2,000 for travel, per PDF). Due to the late arrival of some PDFs, a portion of those funds will not be spent as originally planned.

For fiscal year 2007/2008, the approved IPY funds ($342,000) were received by EC, according to a provisional allocation among three co-applicants: Ayrton Zadra, Pierre Gauthier and Greg Flato. Following recommendations given at the IPY Workshop in Gatineau in Oct 2007, the received funds are being re-profiled and managed internally (i.e. within EC) when needed, as described by the details below (values are approximate):

In Budget Table for recipient Ayrton Zadra:

1a) Estimated expenses in salaries (~ $68,000) are below those in the original budget, due to the late arrival of the 2 PDFs. Part of the funds will be used to support one student project (McGill University, Quebec Region) in 2008. Her project is about the representation of blowing snow processes in numerical models and is very relevant for the development of the Polar-GEM model.

2a) Estimated expenses in equipment (~$24,000) are above those in the original budget. We are acquiring new computers for the PDFs and increasing disk space capacity for the archives.

4b) Estimated travel expenses (~$26,000) are above those in the original proposal. Part of the funds will be used to organize the first TAWEPI Polar-GEM and Sea-ice workshop in March 2008.

In Budget Table for recipient Pierre Gauthier (recipient replaced by Louis Garand):

1a) Estimated expenses in salaries (~ $126,000) are below those in the original budget, due to the late arrival of one of the 3 PDFs.

2a) Estimated expenses in equipment (~$31,000) are above those in the original budget. We are acquiring new computers for the PDFs and increasing disk space capacity for the archives.

4b) Estimated travel expenses (~$9,000) are above those in the original proposal. Part of the funds will be used to fund participation in the first TAWEPI Polar-GEM and Sea-ice workshop in March 2008.

In Budget Table for recipient Greg Flato:

1a) and 1f) Estimated expenses (~ $22,000) in salaries are below those in the original budget, due to the late start of the RA. Note that the salary was originally budgeted as that of a PDF, and that the selected candidate was eventually hired under a contract.

2a) Estimated expenses (~$12,000) in equipment are above those in the original budget. New computed hardware was purchased.

5b) Expenses in publication costs (~$2,200) are slightly above the original estimates.

The revised table of Revenue and Expenditures indicates a surplus of ~$38,000 for the first year of TAWEPI. We are requesting EC to carry this amount forward to the second year (2008/2009).

c) Describe all additional cash contributions in support of this project, their sources and amounts.

Cash contributions are those described in the original proposal, there were no additional contributions.

Please note: The overhead / administrative amounts listed in the original budget are contributions from MRD/EC, and correspond to the standard administrative costs associated with PDFs at EC. No IPY funds are used for this.

d) Describe any in-kind contributions made in support of the project, their sources and estimated values.

In-kind contributions are those described in the original proposal, there were no additional contributions.