STATEMENT OF WORK "A" FOR IMPLEMENTING ARRANGEMENT #8 CONSULTANCY SERVICE FOR THE ENHANCEMENT OF THE CWB REGIONAL NWP SYSTEM TO THE AGREEMENT BETWEEN THE TAIPEI ECONOMIC AND CULTURAL REPRESENTATIVE OFFICE IN THE UNITED STATES AND THE AMERICAN INSTITUTE IN TAIWAN

I. Task Descriptions

1. Task #1 – Support for the WRFVar component of the CWB operational system and improvement of the performance of WRFVar V3

During the year 2010, TECRO's designated representative, the Central Weather Bureau (CWB), implemented OP211 and OP22 (Operational System), which included WRFVar V3.1/WRF V3.1, and WPS V3, in the CWB operational environment. The WRFVar/WRF system has been in operation since 1 April 2010. In 2011 the staff of AIT's designated representative, the University Corporation for Atmospheric Research (UCAR), will work closely with CWB staff, and will continue to provide technical support to CWB staff on the WRFVar component of the CWB operational system.

Based on results from the operational system in 2010, additional efforts on CV3 BE (Background Error statistics) will be made. Although the same CV3 BE input file was used for both the WRFVar and GSI (Grid-Point Statistical Interpolation) data assimilation systems, the detailed implementations of the BE setup and utilization are different in these two systems. In order to improve the performance of WRFVar, it is desirable to adapt some new features from GSI implementation. It is also desirable to perform additional tests on the multiple outer-loops with the different CV3 BE tuning factors. CWB has been operating a high-resolution NWP system with 20/4km resolution since October 2010. The goal for this task is to improve the performance of the WRFVar/WRF operational system at CWB. With this objective in mind, UCAR proposes the following sub-tasks for 2011.

1.1 Support for the WRFVar component of CWB operational system (0.20FTE)

TECRO's designated representation, CWB, will inform AIT's designated representative, UCAR, in a timely fashion (via e-mail or teleconferences) of any WRFVar problems encountered during operation. UCAR will troubleshoot WRFVar-related problems in modules OBS_FGGE_PROC, 3DVAR_OBSPROC, WRFVar and update_bc. UCAR will provide technical consultation, and work with CWB to keep all of the codes synchronized between UCAR and CWB. UCAR will continue to provide training to CWB with regard to basic theory in variational data assimilation and the code structure of WRFVar.

In 2011, several CWB staff will be visiting Boulder to collaborate with UCAR staff. UCAR will provide basic guidance and training on the WRFVar system. UCAR will also discuss

experiment results with CWB, and provide suggestions about their future work. Yong-Run Guo, from UCAR, will visit CWB for two weeks, and CWB and UCAR will exchange their progress on the CV3 BE work (described in Task 1.2).

1.2 Improve the performance of WRFVar (0.5FTE)

AIT's designated representative, UCAR, will continue to improve the performance of WRFVar, as described in the following sub-tasks:

1.2.1 Conduct additional tests on multiple outer-loop with the variable CV3 BE tuning factors

The code for multiple outer-loops with the variable CV3 BE tuning factors, a capability similar to the CV5 BE, has been developed by AIT's designated representative, UCAR, in 2010. In 2011, UCAR will conduct a series of systematic experiments to test the factor settings for Typhoon Morakot, etc. (similar to what was done for CV5 BE in the past), and provide preliminary tuning factor values to TECRO's designated representative, CWB. CWB will carry out the experiments for selected typhoon cases and conduct retrospective experiments for selected periods of time (in the summer and winter). UCAR and CWB will both check and review those results. As part of the UCAR-CWB collaboration, UCAR will provide technical guidance and suggestions to CWB.

1.2.2 Adapt the new features from GSI BE implementation to WRFVar CV3 BE

Based on the CV3 BE work performed in 2010, AIT's designated representative, UCAR, noticed important differences between GSI and WRFVar in the setup and utilization of BE. These included the grid transformation (2-D latitude/vertical-level to 3-D WRF model grid) of CV3 BE, recursive filter specification, and tuning parameters. Note that WRFVar CV3 was originally developed at the National Centers for Environmental Predictions (NCEP). Therefore, the two systems (e.g., GSI and WRFVar) have evolved differently over the past several years. TECRO's designated representative, CWB, and UCAR will work together to investigate the BE implementation in GSI and to identify new features in GSI for possible implementation in WRFVar. In order to improve the performance of WRFVar, UCAR and CWB will adapt some of the new features to WRFVar, such as the weighted results produced from the multiple horizontal scales' recursive filter. Based on the results of this task, UCAR and CWB may create a new BE option for WRFVar. Through this work, CWB will gain knowledge and expertise on the BE formulation of WRFVar. This will be beneficial for future development at CWB.

1.2.3 Evaluation of CV3 "gen_be" code

In 2010, AIT's designated representative, UCAR, developed a new "gen_be" code to generate regional CV3 BE based on regional WRF forecasts. In 2011, UCAR will use this "gen_be" utility for domains at TECRO's designated representative, CWB, and perform preliminary tests with the modified WRFVar code using the WRF regional CV3 BE. Then, UCAR will provide guidance and related codes for this new "gen_be" utility to CWB for further evaluation over an extended period.

1.3 Assess the impact of observing systems on forecast error (UCAR: 0.30 FTE)

Recently AIT's designated representative, UCAR, developed a powerful tool, known as FSO (Forecast Sensitivity to Observations), to assess the impact of observing systems on forecast error. By defining a forecast error norm, the adjoint of the forecast model (WRF) and the adjoint of analysis (WRFVar) can calculate the forecast error sensitivity to each observation used by the analysis. From there, the impact of observations on forecast error can be computed. By doing this for every data assimilation cycle on a routine basis, the results can be very useful for monitoring the operational observing systems. Statistics over a longer period can provide quantitative guidance for improving the forecast scores. In 2011, UCAR will:

(i) Setup a CWB testbed at UCAR. We will select one of the CWB domains and collect one-month of CWB operational data. The CWB current operational configuration will be used as the reference configuration. In 2011, the CWB testbed will be used mainly for assessing the impact of observing systems. It can also be used for testing other developments and solving problems reported from TECRO's designated representative, CWB;

(ii) Further develop and test diagnostic tools of FSO to assess the relative impact of each observation on forecast error and aggregate the information in meaningful and statistically significant ways; and

(iii) Run an observation sensitivity experiment using the CWB testbed over a period of one month and analyze the results. UCAR will provide a report summarizing the impact of observing systems used by the CWB operational data assimilation system, providing recommendations for tuning the observation errors, and commenting on the feasibility of an operational implementation of FSO at CWB.

CWB will assist UCAR on the testbed setup and its initial evaluation.

The following summarizes the schedule and resources required for Task #1:

Performance Period:	
a. Provide support for WRFVar	01/01/11 – 11/30/11
b. Improve utilization of CV3 BE	01/01/11 – 11/30/11
c. Assess the impact of observations on forecast error	01/01/11 – 11/30/11
Resources Required:	1.0 FTE UCAR staff
Deliverables:	
1. Improved CV3 WRFVar code	08/30/11
2. CV3 "gen_be" utility	11/30/11
3. FSO code and related scripts	11/30/11
4. Report on the impact of observations on forecast error	11/30/11

2. Task #2 – Testing and development support for the WRF/DART Ensemble Data Assimilation System

In 2011, AIT's designated representative, UCAR, and TECRO's designated representative, CWB, will continue testing and enhancing the WRF/DART ensemble system at CWB.

2.1 Improve WRF/DART performance

2.1.1 A fast algorithm to get perturbed ensemble boundary conditions for ensemble predictions will be developed in collaboration with WRF/VAR developers. One possibility is to generate a collection of boundary condition perturbations off-line and randomly select from these when generating ensemble forecasts. Another possibility is increasing the efficiency of the existing WRF boundary condition generation tool. The two possibilities will be compared and scripts provided for the most efficient solution.

2.1.2 A new systematic error correction algorithm for ensemble filters was recently developed by Jeff Anderson, from AIT's designated representative, UCAR. UCAR will test the sampling error correction algorithm for Typhoons Sinlaku (2008) and Morakot (2009) on the CWB 45-km domain. Characteristics of both the ensemble analyses and 6-hour ensemble forecasts will be evaluated against best-track observations. The newly developed histogram tools for the evaluation of ensemble predictions will be used to test the ensemble analyses and 6-hour forecasts of the typhoons by UCAR.

2.1.3 TECRO's designated representative, CWB, will develop a new thinned typhoon bogus data scheme for WRF/DART usage. The new thinned (in both horizontal and vertical) CWB typhoon bogus data will be tested with WRF/DART for Typhoon Morakot and Sinlaku cases by UCAR. A set of 72-hour ensemble forecasts twice (00Z and 12Z) daily with 6-h cycle frequency from the WRF/DART analyses will be made and used to evaluate the performance of the new TC BOGUS data and the new version of the WRF/DART system. The ensemble mean and spread of the 72-hour ensemble forecasts will be evaluated using the histogram tools and the best-track observations.

2.1.4 TECRO's designated representative, CWB, will perform extended range ensemble forecasts from WRF/DART analyses for the SOWMEX period and generate diagnostics of the ensemble forecasts. AIT's designated representative, UCAR, will help analyze the results and propose solutions to solve any potential issues.

2.2 Support of WRF/DART at CWB

2.2.1 AIT's designated representative, UCAR, will provide prompt remote consultation and support to TECRO's designated representative, CWB.

2.2.2 AIT's designated representative, UCAR, staff member Hui Liu will visit TECRO's designated representative, CWB, for one week. Hui Liu will present a second WRF/DART tutorial focusing on new WRF/DART developments and detailed diagnostic tools. Other UCAR staff will make presentations via tele-video conference, if requested. During the visit, Hui Liu will also work with CWB staff to implement the new BC generating tools for CWB's operation. One CWB visitor will come to UCAR for WRF/DART training.

2.3 Prepare a paper for publication about WRF/DART at CWB

AIT's designated representative, UCAR, will work with TECRO's designated representative, CWB, to prepare a paper about the performance of WRF/DART at CWB. UCAR will provide guidance and assist CWB with doing the diagnostics. UCAR will write the English version of the paper which will be submitted to "Monthly Weather Review" or "Weather and Forecasting". CWB may write a Chinese version of the paper to be submitted to journals in Taiwan.

The following summarizes the schedule and resources required for Task #2:

Performance Period:

a. Test a new sampling error correction algorithm and new TC bogus data with WRF/DART for typhoon forecasts	1/01/11 – 11/30/11
b. Develop a new tool to quickly generate BC files	1/01/11 – 11/30/11
c. Work with CWB to prepare a paper about WRF/DART at CWB	1/01/11 – 11/30/11
d. Provide support and education about WRF/DART at CWB	1/01/11 – 11/30/11

Resources Required: 0.5 FTE UCAR staff

Deliverables:

1.	An improved version of WRF/DART code and namelists, as well as the tool to generate ensemble BC	11/30/11
2.	Report on the results from WRF/DART improvements and CWB TC bogus data	11/30/11
3.	Tutorial materials for WRF/DART	11/30/11
4.	A paper about WRF/DART performance in CWB operations	11/30/11

3. Task #3 – Support and improvement of water vapor retrievals using CWB GPS networks

AIT's designated representative, UCAR, has previously provided support to TECRO's designated representative, CWB, in the application of data collected from continuously operating GPS (cGPS) stations in Taiwan to retrieve estimates of atmospheric water vapor. UCAR maintains and operates

a data processing system at CWB to generate integrated precipitable water vapor (PW) estimates from the network of approximately 80 GPS stations in Taiwan. The system includes jobs that analyze data in hourly, two-hourly, and daily batches. In addition, data from surface meteorology stations in Taiwan are used to compute surface pressure and temperature values at each of the cGPS stations. Significant products generated from these analysis jobs include the near real-time estimates of PW for monitoring and forecasting activities (hourly and two hourly solutions), as well as the computation of station coordinates and PW estimates within a daily solution. UCAR proposes modest support of this activity for 2011, including the continued analysis of CWB cGPS data as well as the incorporation of stations operating as part of the Japanese GEONET network that are in relatively close proximity to Taiwan.

3.1 Analysis of CWB GPS network

AIT's designated representative, UCAR, will continue to monitor the analysis of the CWB cGPS network for atmospheric purposes. Specifically, UCAR will ensure that all three current processing elements (hourly, two-hourly, and daily solutions) are functioning nominally and will monitor the system for data quality, data latency, and overall product. This task will ensure that the derived PW products are available to both researchers and forecasters who are interested in using these data.

3.2 Addition of Japanese GEONET stations in processing

AIT's designated representative, UCAR, will also include up to ten additional cGPS stations that are part of the Japanese GEONET network of stations. All stations that are within 500 km of Taiwan, and whose data are publicly available with latencies of less than three hours, will be included in the GPS processing system at TECRO's designated representative, CWB. Data from these stations will be used to produce zenith total delay (ZTD) estimates. Because these stations are not in proximity to surface meteorology instrumentation, PW estimates will not be computed. A report summarizing how the GEONET data were included in the CWB analysis and the impact they have on the ZTD analysis at CWB will also be included.

The following summarizes the schedule and resources required for Task #3:

Performance Period:

a. Analysis of CWB GPS Network	01/01/11 – 11/30/11
b. Improved uncertainty parameter in ZTD/PW estimates	01/01/11 – 06/30/11
c. Technical support of GPS analysis	01/01/11 – 11/30/11

Resources Required: .15 FTE UCAR staff

Deliverables:

1. GEONET stations fully implemented in CWB processing along with report summarizing the implementation and impact of ZTD analysis 10/31/11
2. Complete and submit manuscript describing diurnal signal observed in GPS PW data 04/30/11

4. Task #4 – Support the installation and testing of the UCAR High-Resolution Land Data Assimilation System (HRLDAS)

In 2011, TECRO's designated representative, CWB, plans to further advance the update cycle with the coupled WRF/Noah land surface modeling system. During 2010, HRLDAS was successfully implemented into the parallel operational stream at TECRO's designated representative, CWB, validation soil temperature was analyzed and compared to Noah land surface model output in Taiwan, and MODIS satellite land surface states were expanded globally. In 2011, major project goals will be the validation of operational HRLDAS initial states and their influence in the coupled model, parameter improvement based on comparison of output from the operational HRLDAS with Taiwan observation sites, and further development of observed MODIS surface properties to improve how the land model represents actual surface conditions.

During 2011, AIT's designated representative, UCAR, will provide assistance and technical consultation to TECRO's designated representative, CWB, for the further development, operational implementation, and related testing of HRLDAS.

4.1 Evaluate the impact and performance of the HRLDAS land state analysis on the WRF forecast

AIT's designated representative, UCAR, will assist in the continuing evaluation conducted by TECRO's designated representative, CWB, to compare WRF/HRLDAS parallel operational output with observations using the standard CWB near-surface metrics, e.g. 2-meter temperature and humidity and 10-meter winds. Based on the results, UCAR will provide suggestions to adjust HRLDAS/Noah parameters to improve operational near-surface forecasts.

4.2 Evaluate the performance of offline HRLDAS analysis

AIT's designated representative, UCAR, will continue to organize and accumulate flux tower and soil temperature observations received by TECRO's designated representative, CWB, from CWB university collaborators. UCAR will retrospectively run the offline HRLDAS for three years and compare to these observations. UCAR will provide improvement/tuning of the HRLDAS/WRF land surface parameters. Given the findings from this task in 2010, UCAR will provide guidance to CWB and their collaborators on the flux tower observations, which were found to be in serious error.

4.3 Finalize processing of MODIS LAI/fPAR climatology

AIT's designated representative, UCAR, will extend the processing of global MODIS LAI/fPAR observations. Quality control will be done on randomly chosen points globally. Changes will be made to the methodology based on any spurious results. MODIS data will be converted to monthly WRF tiles for inclusion into the WRF model. The climatology will be compatible with the real-time infrastructure developed previously in this task. The global LAI/fPAR climatology will be converted to WRF/WPS format and provided to the WRF community. A journal publication will be written describing the data analysis procedure and the impact of the product on the forecast.

4.4 Visits

Yu-Chun Hung, from TECRO's designated representative, TECRO, will visit AIT's designated representative, UCAR, for four months (likely July to October) and will focus on the evaluation of both operational HRLDAS/WRF and the offline HRLDAS (Tasks 4.1 and 4.2).

Fei Chen, from AIT's designated representative, UCAR, will visit CWB (likely March or April) for an early discussion about the Task 4 progress, to provide training on HRLDAS and observations, and to promote HRLDAS.

The following summarizes the schedule and resources required for Task #4:

Performance Period:	
a. Evaluation of WRF/HRLDAS coupled output	01/01/11 – 09/30/11
b. Three year retrospective testing	01/01/11 – 04/30/11
c. Improvements based on soil and flux measurements	01/01/11 – 09/30/11
d. Expand processing of MODIS observations with validation	01/01/11 – 11/30/11
Resources Required:	0.25 FTE UCAR staff

Deliverables:	
1. Report on WRF/HRLDAS coupled performance	11/30/11
2. Report on offline HRLDAS performance based on Taiwan obs	11/30/11
3. A journal paper on MODIS data and impacts	11/30/11
4. Final report documenting the results of HRLDAS task	11/30/11

5. Task #5 – Improvement of WRF model operational performance

During 2010, AIT's designated representative, UCAR, and TECRO's designated representative, CWB, collaborated on improving the WRF model's operational performance in OP2 at CWB. Significant improvements were made to geopotential height post-processing, typhoon track

forecasts, and elimination of a strong warm bias in the Kain-Fritsch convective parameterization. During 2011, UCAR and CWB will collaborate to extend these improvements, identify and investigate other aspects of WRF forecasts that might be improved. Additionally, UCAR will assist CWB with testing of the new 20- and 4-km WRF grid and provide consultation on other aspects of the operational WRF system, as well as advise CWB visitors to UCAR.

5.1 Investigate the improvement of model QPF (quantitative precipitation forecast) via enhancements to the model physical parameterization schemes (0.5 FTE)

AIT's designated representative, UCAR, will collaborate with TECRO's designated representative, CWB, on investigation and improvement of the forecasts of convective weather phenomena. Prediction of convection over and near Taiwan is a difficult problem, which may be improved by further investigation. During 2010, the Kain-Fritsch convective parameterization was analyzed and modified at UCAR. Tests at UCAR and CWB showed improved WRF forecast performance over the Taiwan area with this modified scheme. UCAR will conduct further analysis and possibly modify the KF scheme to improve its performance on the 45- and 20-km grids. Modifications to the WRF physics code will be tested and, if demonstrated to be successful, will be supplied to CWB. UCAR will assist and mentor CWB staff members that are working on WRF model physics problems.

5.1.1 Modify, test, and tune the Kain-Fritsch parameterization for optimal performance on the 45 and 20 km CWB WRF grids. AIT's designated representative, UCAR, will examine the behavior of the KF scheme on the 45- and 20-km grids and tune the scheme for optimal performance. Components of the scheme that may be tuned include the trigger function, auto-conversion rate, updraft radius, or cloud height. The goal is to improve convective precipitation forecasts without degrading the accuracy of typhoon forecasts.

5.1.2 Collaborate with TECRO's designated representative, CWB, to identify model physics problems. WRF forecast errors might arise due to many different sources. AIT's designated representative, UCAR, will work with CWB to identify cases where the forecast error can be attributed to model physics problems.

5.1.3 AIT's designated representative, UCAR, will evaluate the impact of WRF's shallow convection schemes over the CWB domain with particular emphasis on the low-level moisture fields over the tropical oceans.

5.1.4 Investigate the tendency for modeled convective systems to weaken over Taiwan. TECRO's designated representative, CWB, has identified cases in which convective systems weakened unrealistically once they arrived onshore in Taiwan. AIT's designated representative, UCAR, will attempt to find the cause of this weakening.

5.1.5 Investigate cases of too strong surface winds over land areas. TECRO's designated representative, CWB, has reported that surface wind speeds over the mainland are often too strong. AIT's designated representative, UCAR, will investigate this problem and offer possible solutions such as tuning the PBL scheme or adjusting the model eta levels in the PBL.

5.2 Consult and advise CWB on the operational WRF model (0.1 FTE)

AIT's designated representative, UCAR, will consult and advise TECRO's designated representative, CWB, about the operational WRF model as necessary. This task will include investigation of WRF problems identified by CWB, testing of the 20- and 4-km WRF grids, and provide suggestions for physics, numerics, and name_list options as necessary.

Staff from AIT's designated representative, UCAR, will assist visitors from TECRO's designated representative, CWB, in their WRF investigations.

The following summarizes the schedule and resources required for Task #5:

Performance Period:

a. Improve model QPF via enhancements to physical parameterization schemes 1/01/11 – 11/30/11
b. Consult and advise CWB on the operational WRF 1/01/11 – 11/30/11

Resources Required: 0.6 FTE UCAR staff

Deliverables:

1. Code modifications to WRF parameterization schemes 11/30/11
2. Summary report of the WRF user's workshop 09/30/11
3. Final report on WRF forecast performance 11/30/11

6. Task #6 – Continued interaction on WRF modeling and data assimilation systems

Because the tasks proposed for 2011 require close collaboration between TECRO's designated representative, CWB, and AIT's designated representative, UCAR, the exchange of information and progress between CWB and UCAR in a timely manner is crucial. Effective and efficient communication methods, such as the web pages for the project, and the data transfer "ftp" command must be established and updated on a timely and regular basis. The exchange visits between CWB and UCAR staffs are also necessary to ensure the smooth execution of the project. The following work will be included under this task:

6.1 Update and improve the CWB project web pages on both the CWB and the UCAR sides

With the CWB and UCAR web pages, the updated version of the 3D-Var system, WRF/DART system, experimental results, and progress reports, etc. are easily exchanged between the two groups. In 2011, AIT's designated representative, UCAR, will continue to maintain, improve, and conduct timely updates of the web pages to keep TECRO's designated representative, CWB, informed on current developments.

6.2 Site visit to CWB

To ensure smooth execution of the project, it is desirable for AIT's designated representative, UCAR, to visit TECRO's designated representative, CWB. Such visits are highly valuable to resolve technical problems and report on the progress of the project. It is anticipated that Drs. Hui Liu, James Bresch, and Yong-Run Guo will visit CWB for one or two-week period. In addition, other UCAR staff, including Drs. Bill Kuo, Wei Wang, and John Braun will visit CWB as needed. Additional trips by Yong-Run Guo and James Bresch will be scheduled if needed by CWB. It is also expected that senior CWB staff (Drs. Chin-Tzu Fong and Jing-Shan Hong) will visit UCAR as needed.

6.3 Teleconferences

To ensure smooth execution of the project, periodic telephone conferences will be held. These telephone conferences will focus on specific topics of interest to both parties. The telephone conferences can be initiated by either TECRO's designated representative, CWB, or AIT's designated representative, UCAR, as required by the project.

6.4 Monthly reports

Monthly progress reports will be provided to TECRO's designated representative, CWB, to document the project's accomplishments. These reports will be brief so as not to detract from the FTE dedicated to research.

The following summarizes the schedule and resources required for Task #6:

Performance Period:	
a. Update and maintain both CWB and UCAR CWB project web pages	1/01/11 – 11/30/11
b. Site visit to CWB	1/01/11 – 11/30/11
c. Telephone conferences via Skype	1/01/11 – 11/30/11
Resources Required:	0.1 FTE UCAR staff
Deliverables:	
1. Updated web pages for project	11/30/11
2. Site visits	11/30/11
3. Brief monthly reports to CWB management	2/01/11 - 10/01/11

II. Schedule

Functions	Milestones
Task 1. Support for the WRFVar component of the CWB operational system and improvement of the performance of WRFVar V3	11/11
Task 2. Testing and development support for the WRF/DART ensemble data assimilation system	11/11
Task 3. Support and improvement of water vapor retrievals using CWB GPS networks	11/11
Task 4. Support the installation and testing of the UCAR High-Resolution Land Data Assimilation System (HRLDAS)	11/11
Task 5. Improvement of WRF model operational performance	11/11
Task 6. Continued interaction on WRF modeling and data assimilation systems	11/11

Schedule by Month

TASKS	1	2	3	4	5	6	7	8	9	10	11	12
Task 1												
Provide support for WRFVar	X	X	X	X	X	X	X	X	X	X	X	X
Improve utilization of CV3 BE	X	X	X	X	X	X	X	X	X	X	X	X
Assess the impact of observations on forecast error	X	X	X	X	X	X	X	X	X	X	X	X
Task 2												
Test a new sampling error correction algorithm and new TC bogus data with WRF/DART for typhoon forecasts	X	X	X	X	X	X	X	X	X	X	X	X
Develop a new tool to quickly generate BC files	X	X	X	X	X	X	X	X	X	X	X	X
Prepare a paper about WRF/DART at CWB	X	X	X	X	X	X	X	X	X	X	X	X
Provide support and education about WRF/DART at CWB	X	X	X	X	X	X	X	X	X	X	X	X
Task 3												
Analysis of CWB GPS	X	X	X	X	X	X	X	X	X	X	X	X

Network												
Improved uncertainty parameter in ZTD/PW estimates	X	X	X	X	X	X						
Technical support of GPS analysis	X	X	X	X	X	X	X	X	X	X	X	X
Task 4												
Evaluation of WRF/HRLDAS coupled output	X	X	X	X	X	X	X	X	X	X		
Three year retrospective testing	X	X	X	X								
Improvements based on soil and flux measurements	X	X	X	X	X	X	X	X	X	X		
Expand processing of MODIS observations with validation	X	X	X	X	X	X	X	X	X	X	X	X
Task 5												
Improve model QPF with parameterization enhancements	X	X	X	X	X	X	X	X	X	X	X	X
Consult and advise CWB on operational WRF	X	X	X	X	X	X	X	X	X	X	X	X
Task 6												
Update and maintain CWB and UCAR CWB project web pages	X	X	X	X	X	X	X	X	X	X	X	X
Site visit to CWB	X	X	X	X	X	X	X	X	X	X	X	X
Telephone conferences	X	X	X	X	X	X	X	X	X	X	X	X

III. Budget

The following are the estimated costs for Implementing Arrangement #8A:

Tasks	FTE	Personnel Cost	Travel/Training	Total
Task #1	1.0 FTE	$210,000	$5,000	$ 215,000

Task #2	.50 FTE	$105,000	$5,000	$ 110,000
Task #3	.15 FTE	$31,500		$ 31,500
Task #4	.25 FTE	$52,500	$5,000	$ 57,500
Task #5	.60 FTE	$126,000	$5,000	$ 131,000
Task #6	.10 FTE	$21,000	$4,000	$ 25,000
Total	**2.6 FTE**	**$546,000**	**$24,000**	**$ 570,000**

The budget under Personnel Cost is used to support staff of AIT's designated representative, UCAR, to perform tasks described in this Statement of Work. The figures include benefits and overhead. The Travel/Training budgets in Tasks #1, #2, #4, #5, and #6 are used to support travel to visit TECRO's designated representative, CWB, as well as the cost associated with the training of CWB staff. The travel processed by UCAR also includes the necessary overhead. As stated in the Implementing Arrangement #8A, the total firm fixed price available from CWB to support the tasks, traveling, and meeting expenses described in this Statement of Work will be a total of US$ 570,000. The detailed financial arrangements are described in the Implementing Arrangement #8, Article IV – Financial Provisions.

IV. CWB Joint Team Assignments at UCAR

In order to successfully carry out this CWB-UCAR project, strong collaboration is needed between AIT's designated representative, UCAR, and TECRO's designated representative, CWB. The tasks to be performed by UCAR scientists are detailed in this Statement of Work. CWB staff will collaborate with UCAR scientists on various tasks. Some of the tasks will be performed in Taipei at the CWB. Some of the tasks will be carried out by CWB staff, while they are on assignment to work at UCAR. Specific assignments will be made to most efficiently use the available personnel resources. Assignments for the CWB staff members will be as follows:

- Testing of the CWB operational WRFVar /WRF system for a longer period of time
- Providing the necessary datasets to UCAR
- Participating in WRFVar and WRF/DART data assimilation experiments and results analysis
- Performing WRF physics tests

STATEMENT OF WORK "B" FOR IMPLEMENTING ARRANGEMENT #8 CONSULTANCY SERVICE FOR THE OPERATIONAL IMPLEMENTATION OF AUTONOWCASTER FOR CWB TO THE AGREEMENT BETWEEN THE TAIPEI ECONOMIC AND CULTURAL REPRESENTATIVE OFFICE IN THE UNITED STATES AND THE AMERICAN INSTITUTE IN TAIWAN

Work Plan for Developing a Taiwan Heavy Rain Nowcasting System (2011)

I. Task Descriptions

1. **Task #1** – AIT's designated representative, UCAR, will provide 30 and 60 minute Autonowcaster (ANC) storm activity nowcasts to TECRO's Designated Representative, CWB, and general system support to CWB engineers during the operational demonstration.

The ANC will generate 30 and 60 minute storm activity nowcasts in the Taipei metropolitan area on grid boxes of 5 km x 5 km based on all existing and available data provided by CWB in real time. Initially, UCAR will provide a non-tuned ("first guess") nowcast system to run in weak synoptically-forced environments. CWB software engineers will continue to familiarize themselves with ANC object and source code and collaborate with UCAR engineers to write additional data ingest and conversion modules for the ANC system as needed. UCAR will provide general system support to CWB throughout the year.

1.1 Develop additional data ingest and conversion modules for ANC

The ANC system requires ingesting all available Taiwan operational datasets to generate nowcasting products. AIT's designated representative, UCAR, will work with TECRO's designated representative, CWB, to develop data ingest and format conversion modules for the datasets listed below:

a. Air Force radiosondes
b. Air Force radar data through QPESUMS
c. Chinese satellite data (FY-2C and FY-2D), if available
d. LAPS numerical model fields
e. STMAS
f. Buoy data, if available

1.2 Modify and enhance the system of algorithms and nowcasts in the ANC using Taiwan operational data sets

Datasets from SoWMEX/TiMREX-2008 and selected weakly synoptic cases from August 2010 which will be provided by, TECRO's designated representative, CWB, will be used to adjust the ANC algorithms to a performance suitable for the Taiwan area and its complex terrain. In order to produce a functional nowcast by 1 June 2011, the ANC system will be tested and modified using an enhanced data playback tool referred to as the Taiwan Nowcast Simulator. This simulator tool will be a revision of our existing playback tool, designed to facilitate running new Taiwan data through all of the feature detection algorithms and assist in the modification of algorithms, nowcast membership functions and weights in order to produce nowcasts more relevant to Taiwan weather under weak synoptically-forced situations. This tool will be available for use by CWB and AIT's designated representative, UCAR, personnel. The tuning of the ANC system using the Taiwan Nowcast Simulator will occur over an extended time as new Taiwan data is collected and examined. Algorithms will be developed as needed

to produce predictor fields for Taiwan's complex terrain and the contribution of these new predictor fields toward the overall nowcast will be tested in the playback simulator.

1.3 Run a functional nowcast system to produce 30 and 60 minute precipitation nowcasts in weak, synoptic environments over Taiwan

The ANC system will be modified during the first half of the year to produce first guess deterministic 30 and 60 min storm activity nowcasts for TECRO's designated representative, CWB, using Taiwan ingest data sets. A corresponding, preliminary set of "first guess" probabilistic nowcasts will also be produced for CWB forecasters in 2011 that will require calibration and tuning of the probabilities in 2012 using 2011 datasets. CWB will provide 2010 and 2011 weak synoptically-forced cased to UCAR for testing and evaluating the ANC system.

The following summarizes the schedule and resources required for Task #1:

Performance Period:		
1. Task 1.1 ANC system support		01/01/11-11/30/2011
2. Task 1.1 Write additional Taiwan data ingest modules		01/01/11- 05/31/2011
3. Task 1.2 Taiwan Nowcast Simulator enhanced for use by UCAR and CWB		01/01/11 -05/31/2011
4. Task 1.2 Setup ANC algorithms specific to Taiwan region using TiMREX-2008 and Taiwan 2010 cases		01/01/2011 - 05/31/2011
5. Task 1.3 Produce "first guess"30 and 60 min nowcasts and continued tuning		04/01/2011 – 11/30/2011
6. Task 1.3 "First guess" probabilistic nowcasts and continued tuning		04/01/2011 – 11/30/2011
Deliverables:		
1. Task 1.1 ANC system support		11/30/2011
2. Task 1.1 Write additional Taiwan data ingest modules		05/31/2011
3. Task 1.2 Taiwan Nowcast Simulator enhanced for use by UCAR and CWB		05/31/2011
4. Task 1.2 Modify ANC algorithms specific to Taiwan region using TiMREX-2008 and Taiwan 2010 cases		05/31/2011
5. Task 1.3 Produce "first guess"30 and 60 min nowcasts and continued tuning		11/30/2011
6. Task 1.3 "First guess" probabilistic nowcasts and continued tuning		11/30/2011

2. Task #2 - Localization of VDRAS

Localization of VDRAS is required for Taiwan's subtropical climate and complex terrain. Continued tuning and optimization will be performed based on Taiwan's local observation networks and mesoscale model data. Post-processing analysis will be conducted to find the most relevant fields for convection initiation under the subtropical climate. AIT's designated representative, UCAR, will work with staff at TECRO's designated representative, CWB, and university researchers in Taiwan to localize VDRAS for the applications in Taiwan.

a. Evaluate the use of WRF forecasts and LAPS analysis for the background field used in VDRAS.

b. Evaluate the impacts of considering the terrain height above each range gate on VDRAS performance.

c. Test an improved surface data interpolation scheme (Serp algorithm) for use over Taiwan's complex terrain.

d. Compare the performance of VDRAS with respect to the Serp and STMAS algorithms.

The following summarizes the schedule and resources required for Task #2:

Performance Period:		
1. Use of WRF or LAPS in VDRAS		01/01/2011-05/31/2011
2. Impacts of considering the terrain height above each range gate on VDRAS		01/01/2011 – 11/30/2011
3. Evaluation of Serp and STMAS for VDRAS		01/01/2011 – 08/31/2011
Deliverables:		
1. Use of WRF or LAPS in VDRAS		05/31/2011
2. Impacts of considering the terrain height above each range gate on VDRAS		11/30/2011
3. Evaluation of Serp and STMAS for VDRAS		08/31/2011

3. Task #3 - Assessment of Suitability of Input Data Fields to the ANC and VDRAS

3.1 Assessment of suitability of input fields and surface station data quality

Scientific staff from AIT's designated representative, UCAR, will work with TECRO's designated representative, CWB, and university researchers to continue to assess the quality, availability and selection of operational radar, satellite, radiosonde and surface stations to be used as input data fields to the ANC and VDRAS. This will also include evaluation of numerical model analysis and forecast fields as predictor fields. CWB will provide wind rose plots and panorama photos for

surface stations in Northern Taiwan that are used in the ANC system.

a. Radar and radiosondes
   Continue evaluation of operational data sets and provide recommendations to CWB on modifications.
b. Satellite
   Evaluate combined use of Japan and China geostationary satellite data to produce more frequent updates of satellite information for the ANC system.
c. Surface stations
   i. Evaluate the CWB-provided wind rose plots and panorama photos for the selection of stations used in the ANC system.
   ii. Analysis and evaluation of the Serp surface analysis algorithm and its use in the ANC Surf Interp algorithm using quality controlled surface station data.
d. Evaluate the use of WRF forecasts and LAPS analysis fields as reliable predictor fields for stability, humidity, and vertical motion.

The following summarizes the schedule and resources required for Task #3:

Performance Period:		
1. Report and recommendations of the assessment on each data type		01/01/2011 – 11/30/2011
2. Select stations to use in ANC and VDRAS		01/01/2011 – 11/30/2011
3. Report on the evaluation of the Serp and STMAS algorithm		01/01/2011 – 11/30/2011
4. Select WRF and LAPS fields to be used as predictors		01/01/2011 – 11/30/2011
Deliverables:		
1. Report and recommendations of the assessment on each data type		11/30/2011
2. Select stations to use in ANC and VDRAS		11/30/2011
3. Report on the evaluation of the Serp and STMAS algorithm		11/30/2011
4. Select WRF and LAPS fields to be used as predictors		11/30/2011

4. Task #4 - Building Climatology for Nowcasting in Taiwan

AIT's designated representative, UCAR, will work with TECRO's designated representative, CWB, and university researchers to help with the subtasks listed below. The purpose of these activities will be to help formulate ANC nowcasting rules for Taiwan. During 2011 the focus will be placed on examination of afternoon thunderstorms under weak synoptic conditions using data collected during the 2008 SoWMEX/TiMREX field campaign.

Subtasks include:

a. Develop climatological interest maps of storm initiation versus wind velocity and atmospheric stability. This will include running VDRAS on multiple days.
b. Investigate factors related to convective storm longevity and motion.
c. Construct improved maps of terrain-induced vertical velocity as a function of wind velocities and directions.

The following summarizes the schedule and resources required for Task #4:

Performance Period:		
1. Climatological interest maps of storm initiation versus wind velocity		01/01/11 - 11/30/2011
2. Construct maps of terrain enhanced vertical motions for selected wind fields		01/01/11 - 11/30/2011
Deliverables:		
1. Climatological interest maps of storm initiation versus wind velocity		11/30/2011
2. Construct maps of terrain enhanced vertical motions for selected wind fields		11/30/2011

5. Task #5 - ANC training workshop

AIT's designated representative, UCAR, will work with TECRO's designated representative, CWB, and university researchers to conduct a nowcasting training workshop at CWB at an agreed upon time in 2011. Training topics include nowcasting concepts, and modification and tuning of ANC and VDRAS for Taiwan, and 1-2 nowcasting modules using Taiwan's cases.

The following summarizes the schedule and resources required for Task #5:

Performance Period:		
1. A three-day training workshop at CWB		06-01-2011 – 11/30/2011
Deliverables:		
1. A three-day training workshop at CWB		06/1/2011-11/30/2011

6. Task #6 – Planning Field Experiment in Taipei Basin

AIT's designated representative, UCAR, will participate with TECRO's designated representative, CWB, and university researchers in Taiwan in planning an experiment for the collection of an enhanced data set over northern Taiwan. The purpose of this experiment is to collect high time and space resolution of the wind and stability conditions over northern Taiwan with a particular emphasis on the Taipei Basin. The emphasis will be on weak synoptically-forced situations; thus the

proposed time period for a field program is a one-month period between June -August 2012, sponsored by Taiwan. Data from the experiment will be used to improve the understanding of convective storm initiation and evolution in northern Taiwan so that predictors can be developed for the ANC.

The following summarizes the schedule and resources required for Task #6:

Performance Period:		
1. Participate in the planning for the northern Taiwan Experiment in 2012		08/01/11 – 11/30/11
Deliverables:		
1. Participate in the planning for the northern Taiwan Experiment in 2012		11/30/11

7. Budget

The following are the estimated cost for Implementing Arrangement #8B:

Tasks	**Personnel Costs**	**Travel/Training**	**Total**
Task #1	$105,000	$0	$105,000
Task #2	$90,000	$0	$90,000
Task #3	$86,000	$0	$86,000
Task #4	$90,000	$0	$90,000
Task #5	$25,000	$20,000	$45,000
Task #6	$30,000	$10,000	$40,000
Total	**$426,000**	**$30,000**	**$456,000**