

(Instructions and Distribution on Reverse)

1. CONTRACTOR: SSAI	2. CONTRACT NO.: NNG12HP06C	3. TASK/REVISION NO.: CY4 0 04
4. JOB ORDER NO./PROJECT:	5. FLIGHT HARDWARE/SOFTWARE; CRITICAL GSA (IF, YES, OBTAIN BLOCK 16 CONCURRENCE): YES <input checked="" type="checkbox"/> NO	6. DESIGNATED FLIGHT ASSURANCE MGR.:
7. DESCRIPTION OF WORK TO BE PERFORMED (OBJECTIVES OR RESULTS DESIRED): GEOS Data Assimilation System Development, Integration, and Application		
8. TASK DOCUMENTATION REQUIREMENTS/DELIVERABLE ITEMS: See Attached		
9. PERFORMANCE/MILESTONE SCHEDULE: February 1, 2015 – January 31, 2016		
10. QUALITY ASSURANCE REQUIREMENTS:		
11. TRAVEL, MATERIALS, ETC., KNOWN TO BE REQUIRED:		
12. OTHER (FUNDING, NTE, HOURS, ETC.): Estimated Cost Fixed Fee Estimated Total Cost-Plus-Fixed Fee \$1,107,822		
13. TASK ORIGINATOR/MONITOR/CODE/PHONE: Ricardo Todling		18. THIS TASK ORDER IS ISSUED PURSUANT TO THE TERMS OF THE CONTRACT.  CONTRACTING OFFICER'S SIGNATURE/ DATE Ayana A. Briscoe Contracting Officer TYPED OR PRINTED NAME
14. BRANCH APPROVAL:	15. DIVISION CONCURRENCE:	
16. CONTRACTING OFFICER'S TECHNICAL REPRESENTATIVE: Stephen Cohn		
17. CONTRACTOR SIGNATURE:		

Science Systems and Applications, Inc.
NNG12HP06C
Task Order Statement of Work

Task Order Number: CY4_04_Mod0

Task Order Title: GEOS Data Assimilation System Development, Integration, and Application

1.0 Task Monitor (TM):

Name: Ricardo Todling
Organization: GMAO:GMAO
Email Address: ricardo.todling-1@nasa.gov

2.0 Description of Work to be Performed

There are significant changes from CY3 to CY4, as indicated in red below.

The objective of this task is to provide collaboration and support for the development of the GMAO joint atmospheric analysis system with the National Centers for Environmental Prediction (NCEP), the development of the ADAS and ODAS for NASA applications, especially with a focus on assimilation of satellite data, the development of associated diagnostic tools, and the development of the next generation atmospheric and ocean analysis systems.

Highest overall priorities for this period: (i) support updating the GMAO Operational System to a 4d-ensemble-variational hybrid system, and (ii) support bringing the coupled-ADAS to parallel OPS experimentation

Subtask A: Atmospheric analysis system development

The contractor will contribute to the development and maintenance of the Grid-point Statistical Interpolation (GSI) system and to the development of its 4-D extension, in collaboration with the responsible GMAO TM and with NCEP, specifically:

- i) Continue overall integration efforts related to the development of the GEOS-5 ADAS. This should include conducting assimilation experiments to exercise the system and evaluate its performance, with a focus on improving forecast skill and analysis quality.
- ii) Perform ongoing compilation and tuning of GEOS-5-based background error statistics to improve forecast skill. This effort is to be conducted in the context of the hybrid variational-ensemble analysis. Work to modify the software for the background error generation to accommodate terms of a model error covariance formulation for weak constraint 4DVAR. Attention should be given to DTC's so-called gen-be software that

provides an enhanced tool for background error covariance generation. Test this by running with a background error code generated with DTC's software.

- iii) Assist in developing the capability to calculate observation-minus-background residuals using a high-resolution background in GSI. The capability should permit the minimization to be done at resolutions other than the background resolution. The capability should accommodate both 3d- as well as 4d-analysis strategies. Development within GSI should keep in mind the community applicability of the software.
- iv) Assist in testing the observation error correlation component in GSI. Once software provided by the TM is shown to work properly, cycling tests should be conducted to examine the impact of changes in the overall DAS.
- v) Work on a 4d extension of GSI's ability to fix quality control choices in the first outer-loop to any subsequent loops. Extended capability should work in both traditional and hybrid contexts. This is to be done along the lines of work done in the previous year in the context of 3d-var. Make sure implementation gets embedded within the main GSI development path (not simply sitting in a separate branch in the repository).
- vi) Continue to test GSI's capability to use GOCART aerosols to influence radiative transfer calculations in the CRTM. A followup to this investigation should be to study the impact of greenhouse gases in CRTM calculations (exercising the presently available ability in GSI, but for the GMAO model). Some of the testing here should involve experiments over certain periods covered by MERRA-2, with comparisons made to assess impact of aerosols and GHG.
- vii) Continue to contribute to the 4DVAR system by further improving computational performance of tangent linear and adjoint models (see subtask B).
- viii) Provide support for continued testing and evaluation of present implementation of the ensemble hybrid 3D and 4D capability within GEOS. This should include providing support to GMAO's operational group when inheriting the developers' implementation of the hybrid capability. The focus for this period should be in helping evaluate the 4D-ens-var hybrid extension. Coordination with the effort to implement, test and evaluate traditional 4DVAR should take place at various stages.
- ix) Continue to identify improvements needed in the system, especially those required for the assimilation of satellite data streams identified in Task 13 (Satellite Data Assimilation).
- x) Continue development of a GEOS coupled atmosphere-ocean assimilation system (AODAS). This should be among the highest of priorities within this overall task. Promote SST analysis to a level that can be tested within a parallel operational experiment. Attention should be given to merge and integration of SST analysis in consideration of 3d-hybrid-variational system; that is, the ability to analyze SST should

be brought into the ensemble Kalman filter (EnKF) system. See subtask C for further details on the coupled-DAS effort.

- xi) Integrate GEOS diagnostic tools to development scripts used to run experiments with GMAO DAS. These entail: (a) program for calculating forecast statistics; (b) program for calculating observation residual statistics; (c) automate visualization of ensemble statistics including ensemble spread, 0-hr observation impact, and ensemble mean meteorological fields.
- xii) Continue to maintain a common software repository to track development and aid integration. Coordinate, as often as possible, development efforts of GMAO and NCEP/EMC scientists. Make sure GSI changes by GMAO members are passed to NCEP.
- xiii) Provide documentation of the ADAS, and training and support to GMAO scientists in GSI methodology and the GMAO ADAS to enable GMAO scientists and collaborators to interact with the system and contribute their own Fortran-90 code in a manner that conforms to coding practices used in the GMAO.
- xiv) Provide support to GMAO Integration and Test (GMAO IT) group for validation and operational implementation of new system releases. Thorough testing at operational resolution must be conducted before releasing tag to Operations.

Subtask B: Development and implementation of tangent linear and adjoint models for the next-generation cubed-sphere dynamical core

The contractor will support the development of applications of the tangent linear and adjoint models (TLM and ADM) of the hydrostatic version of the cubed sphere dynamical core. These applications include 4DVAR, model sensitivity, observation sensitivity and impact, singular vectors and tracer assimilation as specified by the GMAO Lead Scientist for Assimilation.

The contractor shall perform the following:

- (i) Maintain, and upgrade where needed, the ADM and TLM of the cubed-sphere core. Complete ongoing test strategies for using reduced internal dynamics time steps for improved efficiency, and optimize check-pointing and re-calculation requirements for performance in 4DVAR.
- (ii) Complete test of upgrades to TLM and ADM moist physical parameterization schemes, specifically convection and large-scale precipitation.
- (iii) Promote upgrades to operational generation of observation impacts (adjoint code), including revisions in trajectory handling to allow operations to increase resolution of adjoint integrations.

Subtask C: Ocean data analysis system development and documentation

Particular focus for ODAS development is the initialization of the ocean model used in the GEOS atmosphere-ocean general circulation model (AOGCM) for global coupled forecasts. Support will include continued developments to improve the ODAS performance and to assimilate all relevant observations (as specified by the TM), optimization of code performance, assimilation tests conducted for model/module evaluation. Support for developments by collaboration with scientists external to the GMAO will be provided as approved by the TM.

- (i) Develop improvements to the GEOS integrated ocean data assimilation system, with focus on the operational implementation with MOM5 and the performance in ocean reanalyses and impacts on short-term climate predictions. Improvements shall focus on covariance modeling, bias corrections, or other system developments needed for the assimilation of altimeter data and development of the infrastructure to assimilate remotely sensed sea surface salinity and sea ice (see below).
- (ii) Continue to test and improve the methodology and implementation for high-resolution versions of the GEOS-5 AOGCM; undertake software developments with HEC accelerator technology to improve computational performance where appropriate. This activity shall take place in coordination with the overall goal of developing a weakly-coupled AODAS.
- (iii) Coordinate with the GMAO atmospheric data assimilation group in the implementation of coupled ocean-atmosphere assimilation, focused on sea surface temperature (SST). The primary goal for this period is to resolve software redundancies preventing GMAO from having a single GCM supporting both atmosphere-only and atmosphere-ocean endeavors. The diurnal-layer developed under the atmospheric model shall be brought into the context of the coupled-model.
- (iv) Bring SST analysis capability into the EnKF software. Devise mechanism(s) for perturbing SST analysis to generate desirable ensemble spread.
- (v) Integrate the Miami wave model into the coupled-model. Work to develop a sea-spray parameterization coordinating with the GMAO Aerosol group.
- (vi) Evaluate and continue to improve the sea-ice assimilation capability that assimilates sea-ice concentration and also corrects ocean near-surface temperature and salinity.
- (vii) Continue the development of a system to assimilate remotely sensed ocean color.
- (viii) Provide support for the development and testing of data assimilation capabilities for the ocean biology model.

- (ix) Maintain source control for the ODAS under CVS repositories; undertake regular regression tests for code robustness.
- (x) Document the ODAS and system performance in NASA Technical Reports and/or peer-reviewed publications.

3.0 Special Requirements

None

4.0 Performance/Milestone Schedule

The GMAO Contract Year 4 POP is February 01, 2015 - January 31, 2016

The main milestones for this period are as follows:

March-April: Provide GMAO OPS with 4d-ensvar system for parallel testing.

June-July: Provide GMAO OPS update that incorporates SST analysis in both central and ensemble DAS. This should preferably use the AOGCM running in AGCM-mode.

October-November: Provide OPS with ability to have a parallel experiment using a version of the coupled-AODAS.

NOTE: The October-November update depends on the overall decision by GMAO on priorities related to model vertical level changes; this might push the October-November AODAS update to the next period.

5.0 Deliverables/Reporting Requirements

All subtasks will provide software/algorithm documents and user guides in conformance with GMAO guidelines as appropriate.

Subtask A:

Optimized GEOS-5 DAS (in terms of both product quality and system efficiency) that is easily configurable to run on all GMAO-accessible computational platforms; pre- and near-operational versions of 4D-like strategy, which can be run efficiently at operational resolution; promote current prototype configuration of 3d-ensemble variational analysis to operations by spring 2014; promote 4d-ensemble-var to operations by end of spring 2015. Document system performance. Report on areas and specific suggestions for code enhancement and code areas amenable to optimization.

Subtask B:

- Provide necessary support for maintenance of ADM and observation impact tools.
- Provide documentation for TLM and ADM.

Subtask C:

- Fully merged AOGCM that can be used in both coupled and uncoupled modes (same software, same compilation; simple resource file trigger).
- Documentation of the ODAS in the form of a technical memorandum.

6.0 Other Information Needed for Performance of Task

Five 1-person, 1-week domestic trips.

Two 1-person, 1-week foreign trips:

47th International Liege Colloquium on Ocean Dynamics Marine Environmental Monitoring, Modelling and Prediction, Liege, Belgium

Theoretical aspects of ensemble data assimilation for the Earth system, Les Houches, France.

Local travel for training purposes, not to exceed 10 person-days, will be authorized at the request of the TM or the GMAO Chief.

7.0 Data Rights

N/A

8.0 Safety

Staff on this task will comply with federal, state, local, and center safety regulations. This will be accomplished through management emphasis, technical training, and personal responsibility. Staff will participate in safety orientation and training in accordance with the contract Safety and Health Plan, and work within the requirements of that plan.

9.0 Risk

Contractor shall provide ongoing risk assessment and mitigation in performance of the Task Order. Priorities shall be re-evaluated as appropriate with the TM. Cost and schedule performance shall be assessed on a regular basis (no less frequently than monthly) and significant variations discussed and acted on in consultation with the TM and COTR.

10.0 Proposed Cost and Fixed Fee

In accordance with Paragraph B.5, of the contract, propose the Cost and Fixed Fee amount.