

CONNECTING SENSOR WEB AND EARTH SYSTEM MODELS

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1. INTRODUCTION

Earth observation (EO) through sensors is the most important method for measuring the state of the Earth system. In recent years, one of the most significant technological developments in EO is the EO sensor web. The EO sensor web is a web of interconnected, heterogeneous, geospatial sensors that are interoperable, intelligent, dynamic, flexible and scalable. The sensor web approach employs new data acquisition strategies and systems for integrated Earth sensing that is much more flexible, reliable, promptly, and economically than the traditional stand-alone sensing. On the other hand, scientists are increasingly relying on digital Earth system models (ESM) for understanding the functioning of the Earth system and predicting its future state. ESM requires initial states to run as well as ground truth to validate the model. Those information can be provided through sensor web observations. This paper presents a study to develop service-oriented general framework for facilitating the dynamic connection and interoperability between the EO sensor web and Earth system models.

2. THE SELF-ADAPTATION CONCEPT AND THE SEPS FRAMEWORK

The general framework is inspired by the self-adaptation concept, a central piece of the control theory widely used in engineering systems. Such systems contain a predictor and a measurer. The predictor takes initial condition and makes an initial prediction and the measurer then measures the state of a real world phenomenon. A feedback mechanism is built in that automatically feeds the measurement back to the predictor. The predictor takes the measurement against the prediction to calculate the prediction error and adjust its internal state based on the error. Thus, the predictor learns from the error and makes a more accurate prediction in the next step.

By adopting the self-adaptation concept, a Self-adaptive Earth Predictive System (SEPS) concept has been developed to enable the dynamic coupling between the sensor web and ESM. The concept treats ESM and EO sensor web as integral components of the SEPS coupled by the SEPS framework. EO measures the Earth system state while ESM predicts the evolution of the state. A feedback mechanism processes EO measurements and feeds them into ESM during model runs or as initial conditions. A feed-forward mechanism analyzes the ESM predictions against science goals for scheduling optimized/targeted observations. The SEPS framework automates the Feedback and Feed-forward mechanisms. Based on open standards, a general SEPS framework has been developed to support the interaction between ESM and EO. The framework consists of five subcomponents including Data Discovery and Retrieval Services (DDRS), Data Pre-processing, Integration, and Assimilation Services (PIAS), Science Goal Monitoring Services (SGMS), Data and Sensor Planning Services (DSPS), and Coordination and Event Notification Services (CENS).

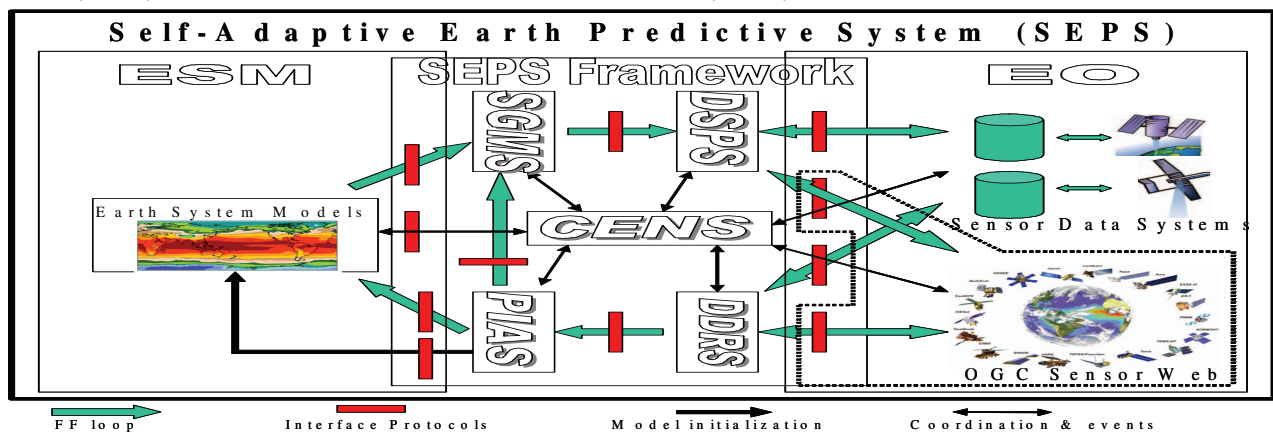


Figure 1. shows the architecture of the SEPS framework.

3. APPROACH FOR INTEROPERATION WITH EARTH SYSTEM MODELS

The SEPS aims at bridging existing Earth science models and the Sensor Web. From Figure 1, we can find that major interoperation between ESM and SEPS takes place in the interfaces between PIAS and ESM and between SGMS and ESM. Modern Sensor Web technology is based on service-oriented architecture that utilizes Web service standards and technology, while most of Earth science models still use conventional server/client architecture or even a single system under the Earth Science Modeling Framework (ESMF). A mechanism to bridge the two worlds together has been studied.

3.1 Earth science modeling framework (ESMF)

ESMF is a framework to build earth science models and to leverage scientific models developed in different languages, including FORTRAN and C. Complex models can be built up within the framework using grid components and coupler components. Grid components process data and complete computation. Coupler components bridge different components to enable communication between them. Hierarchical architecture is enforced. A component can be viewed in the 'scope' of a computer program. Coupling between components can only be done within the scope. These form the basic structure of the ESMF models. To interact with other components, they exchange states. There are two states in ESMF: the import state and the export state. ESMF is the standard for the model interoperability in the Earth system modeling community.

3.2 Architecture for Interoperation between ESMF models and SEPS Services

In this project, interoperations between ESMF models and SEPS services is done by exchanging and modifying the import and export states of the outmost component of a model. Possibly, some intermediate result or export states may be accessed and exposed through standard SEPS Web service interfaces. Figure 2 shows the architecture and its underlying mechanism for supporting the state exchange between ESMF models and service-oriented geospatial Web services under the SEPS framework.

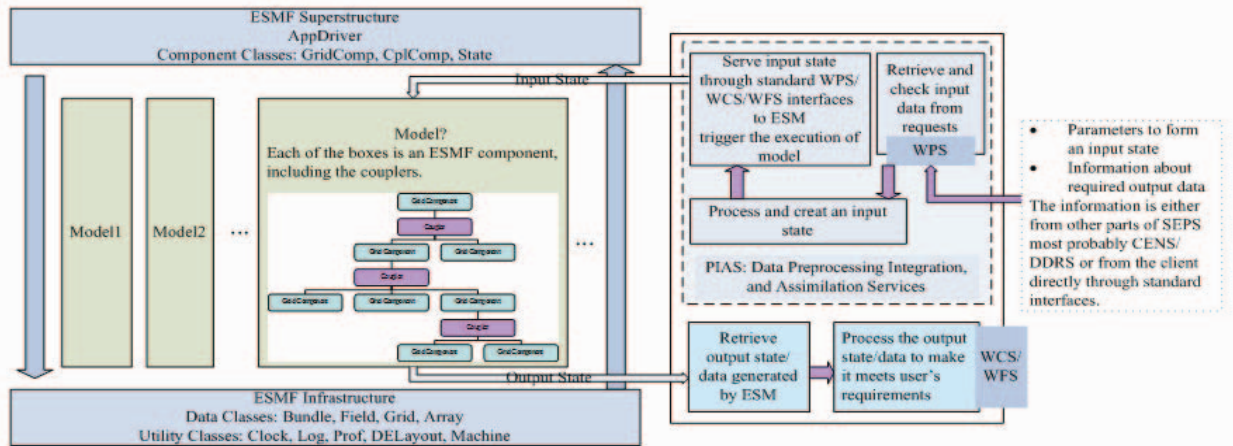


Figure 2. State exchange between SEPS and ESMF

4. IMPLEMENTATION AND PRELIMINARY RESULTS

The exchange of states between the SEPS framework and ESMF has been implemented as an OGC WPS process. The WPS endpoint is deployed at <http://data.laits.gmu.edu:8081/wps/WebProcessingService> for the testing purpose. Experiments have been carried out on interoperating with selected Earth science models. The Community Atmosphere Model (CAM) was one of the selected models. Further information about the model can be found at <http://www.cesm.ucar.edu/models/atm-cam/>. A prototype was developed to establish a data link between CAM and SEPS through standard geospatial interfaces by providing/retrieving Import/Export states to/from the ESMF model. The test page is available at http://data.laits.gmu.edu:8081/wps/ESMFDemo_test.html. This demonstration shows that it is possible to change the initial state of the ESMF models and retrieve the resulting states of the running ESMF models. This preliminary results helped us refine the architecture to build interoperation between SEPS and ESMF-enabled Earth system models.