LIS-NEMS Prototype Coupled System

James Geiger[1,2], Sujay Kumar[1,3], Shujia Zhou[4,5], Christa Peters-Lidard[1],
Jesse Meng[6], Mike Ek[6], Ken Mitchell[6], Mark Iredell[6], Hann-Ming Henry Juang[6], Weiyu Yang[6]

[1]Hydrological Sciences Branch 614.3, NASA/GSFC
[2]Science Data Processing Branch 587, NASA/GSFC
[3]Science Applications International Corporation
[4]Software Integration and Visualization Office 610.3, NASA/GSFC
[5]Northrop Grumman Information Tech
[6]Environmental Modeling Center, NOAA

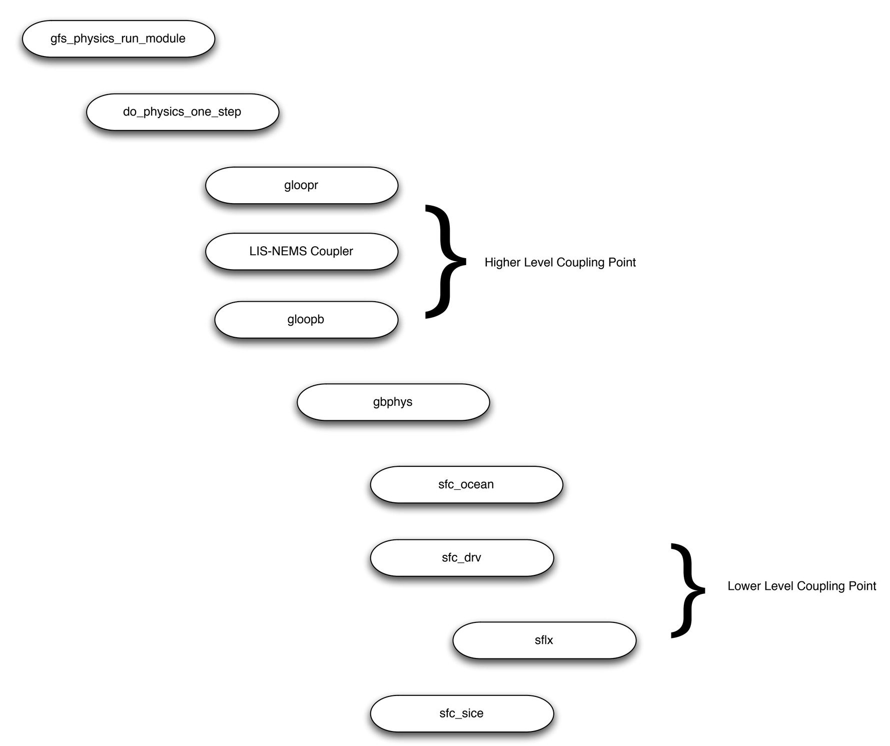
Introduction

This presentation discusses the prototype system for coupling NEMS and LIS. NEMS is NCEP's National Environmental Modeling System. It is an Earth System Modeling Framework (ESMF) compliant system used to perform regional and global forecasts. Land Information System (LIS) is a land surface modeling and data assimilation system developed in the Hydrological Sciences Branch at NASA/GSFC. The goal of this project is to integrate LIS and NEMS to enable LIS as the land surface component in the coupled system. LIS supports the use of multiple land surface models, provides a representation of sub-grid scale land surface heterogeneity, and supports tools for land surface data assimilation. These capabilities can be used to improve the characterization of land surface states in the coupled LIS-NEMS system. The use of LIS also provides consistency between initialization (offline spin-ups) and forecasting (in coupled mode). This presentation reviews the status of and preliminary results from a prototype coupled LIS-NEMS system.

The prototype system was developed by reorganizing the physics component of NEMS and integrating LIS as an independent land surface modeling component. The interactions between LIS and NEMS are specified through explicit interface implementations consistent with the paradigms of the Earth System Modeling Framework. The potential mismatches in landmasks of NEMS and LIS were resolved by configuring LIS to adopt the same landmask and surface datasets used in NEMS. The NEMS system currently employs a custom, highly irregular domain decomposition in a multi-processor environment and LIS typically employs a regular domain decomposition scheme. The translation of import and export states between LIS and NEMS required a redistribution scheme, which was developed using tools from the ESMF infrastructure software. The redistribution code will be integrated in the ESMF-compliant couplers as part of the future work, to enable the current prototype to run on a multiprocessor environment.

NEMS Calling Tree and Potential Coupling Points

The current NEMS structure processes land surface in a single column manner and is tightly interlaced in the physics component. The integration of LIS as an independent, ESMF-compliant gridded component requires the separation of land physics with the underlying associated grid and processor information. The goal of the prototype is to couple LIS as a separate component, but at the same time minimize the associated impact on the existing system. We considered two different coupling locations in the NEMS calling tree (1) Lower level coupling point and (2) Higher level coupling point.



Lower Level Coupling

At this level, the land physics is called for each grid point (in a single column manner). To use LIS in a similar fashion would limit a number of key features.

-- The support of sub-grid tiling requires significant I/O overhead.
-- Data Assimilation within LIS becomes intractable as a result of the fact that observation operator becomes computationally expensive
-- The use of different land surface models (other than Noah) becomes limited and requires initialization support in NEMS
-- LIS' I/O becomes very intensive

These issues run counter to our design goals.

Higher Level Coupling

At this level, the fully gridded representation of the land surface is available and is the lowest structural level at which a coupling scheme compliant with our design goals is feasible. However, the current level of ESMF compliance in NEMS does not extend to this location. As a result, translating the irregular decomposition scheme used in NEMS to a regular decomposition in LIS becomes difficult. For this prototype, we circumvent this issue by limiting the simulations to a single processor. Further, land, ocean, and sea-ice processes are all contained and managed within the same routine within NEMS (gbphys). These lower level interactions had to be carefully reengineered to avoid conflict with the higher level coupling.

LIS-NEMS Coupler

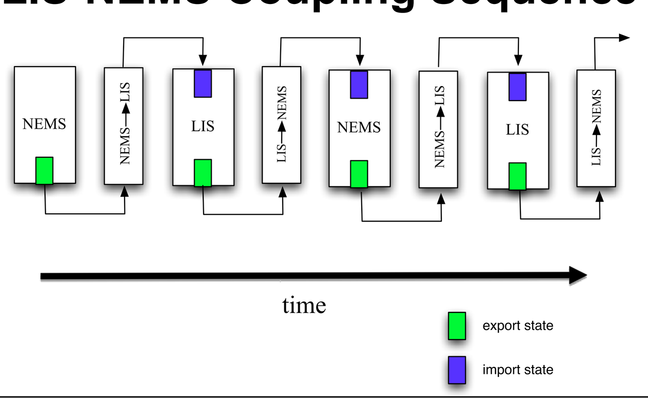
LIS-NEMS coupler was inserted at the higher level coupling point and it performs the following sequence of computations:

Derives import states from sfc_fld and flx_fld as in gloopb.
Performs common computations to local variables.
Runs LIS.
Retrieves export states from LIS.

Implementation Issues

LIS and NEMS must both run on the same full T126 Gaussian grid.
LIS-NEMS coupled system must be run as a 1-process job.
LIS' Gaussian support is only for full Gaussian grids.
Mismatches between LIS' and NEMS' land/sea mask and surface parameter datasets were resolved.
LIS was configured to use the same version of Noah as that of NEMS.
LIS is compiled as a library using different compiler flags and default storage sizes from NEMS.

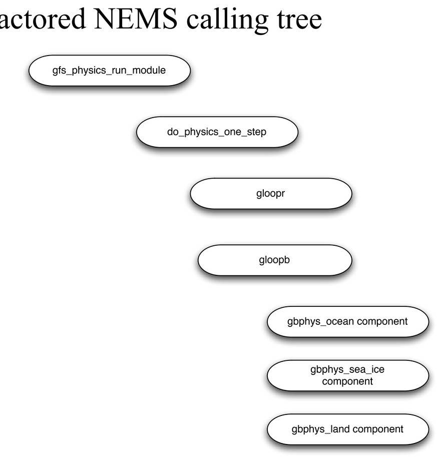
LIS-NEMS Coupling Sequence Diagram



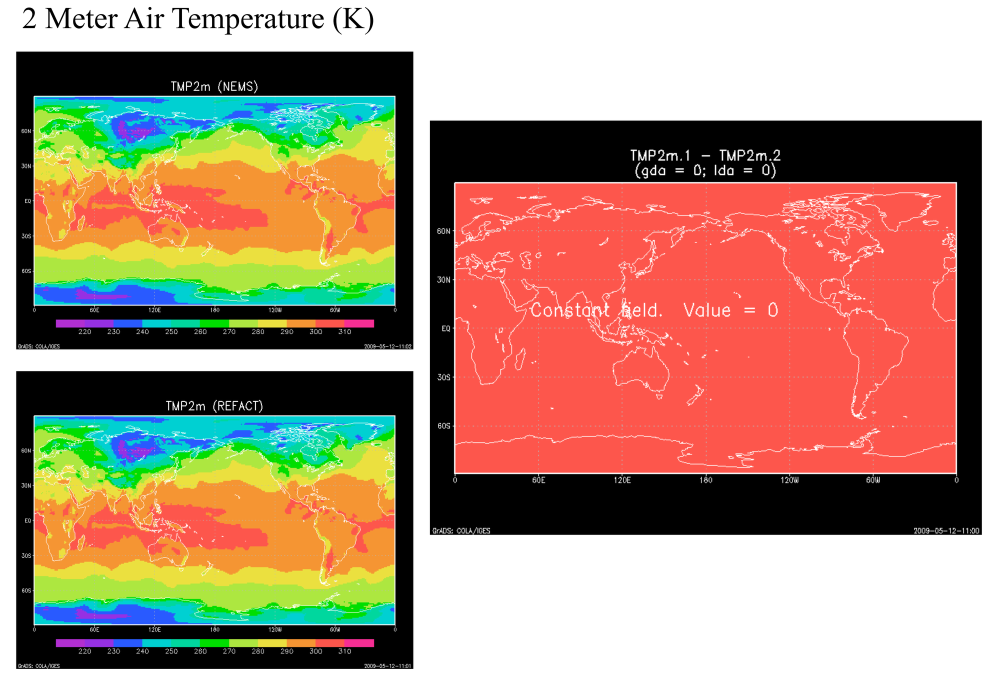
Concurrent Work

A refactored version of NEMS is also in development. The goal of this refactored version of NEMS is to allow NEMS to process land, water, and sea ice points independently. The current state of NEMS (gbphys) processes the surface in blocks of data, using conditional statements to control land, water, and sea ice processing. This causes difficulties with respect to deriving import states for LIS and with respect to incorporating the export states from LIS back into NEMS. This refactored version will alleviate these issues. This version will enable a fully ESMF-compliant coupled system, that will also help NEMS with the incorporation of other ESMF-compliant ocean and sea-ice components.

Refactored NEMS calling tree



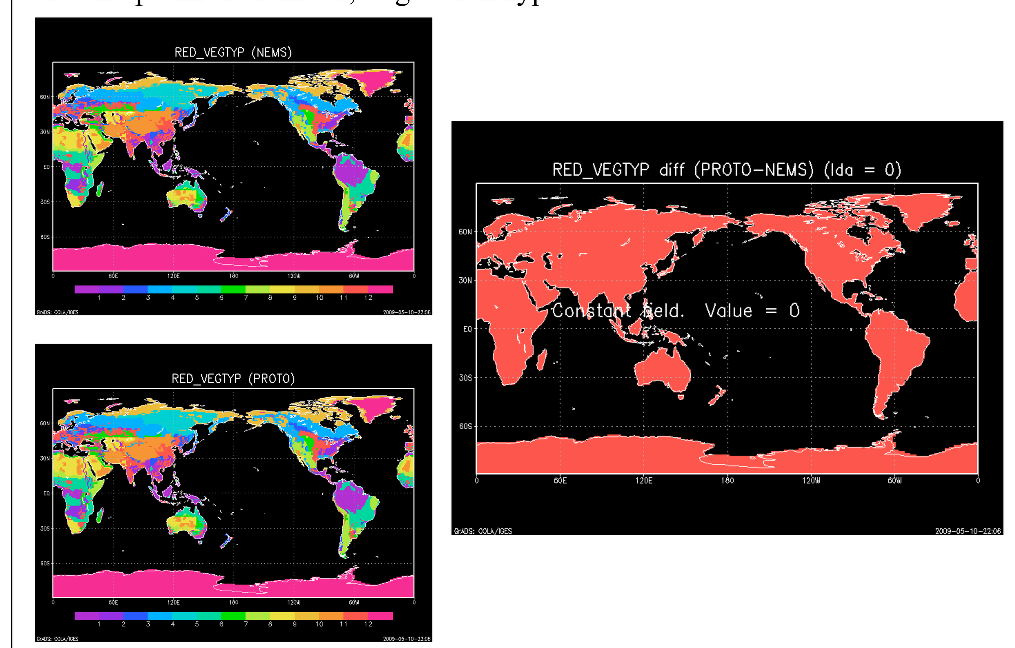
2 Meter Air Temperature (K)



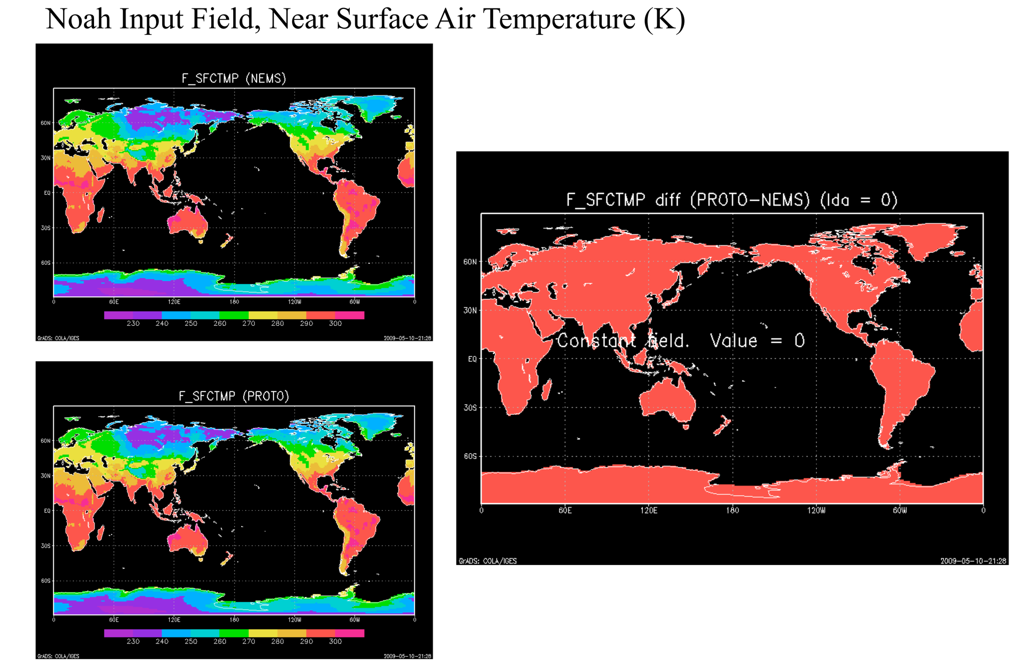
Benchmarks of First Time-step

Here a number of comparisons between the default NEMS and the coupled LIS-NEMS prototype is presented. The figures show that the input Noah specific parameters from the two systems are either identical or differ by floating point noise. All input variables for Noah's physics routine are identical between the LIS-NEMS prototype and NEMS. The output variables from the two systems are comparable and the differences are a result of floating point noise identified in the Noah specific parameters. Note that only a handful of the possible intercomparisons are shown here. In the Figures, lda = difference between the averages only over land points; gda = difference between the averages over all points.

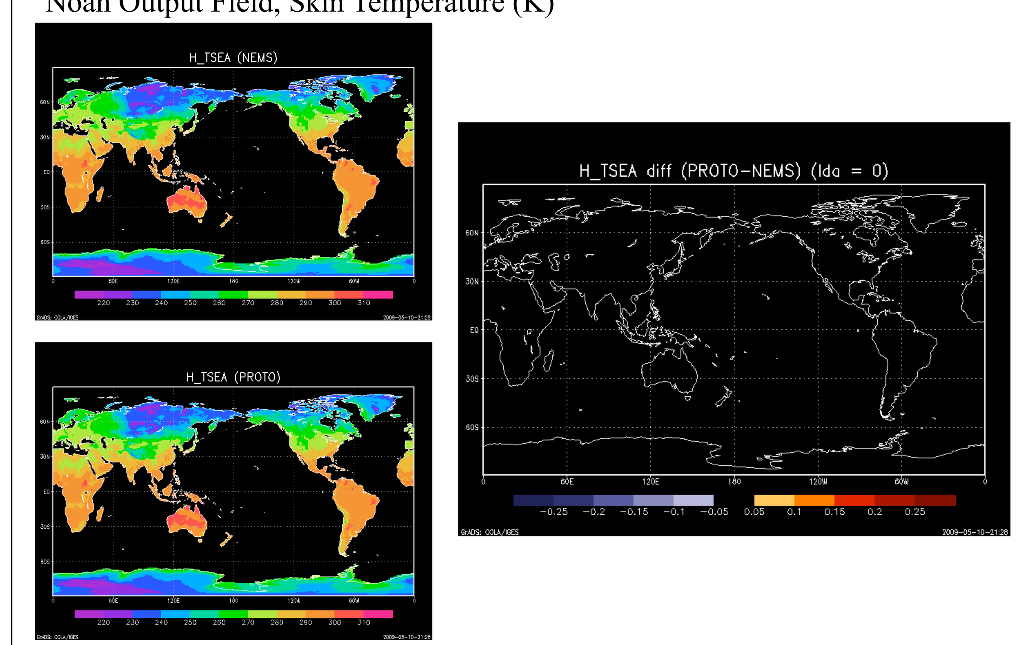
Noah Specific Parameter, Vegetation Type



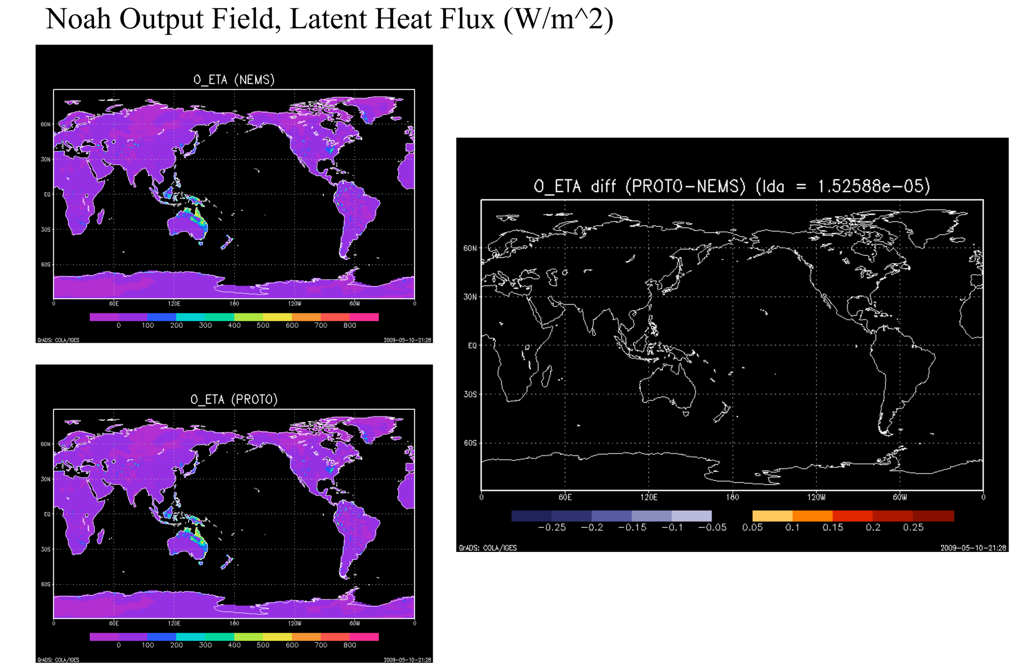
Noah Input Field, Near Surface Air Temperature (K)



Noah Output Field, Skin Temperature (K)



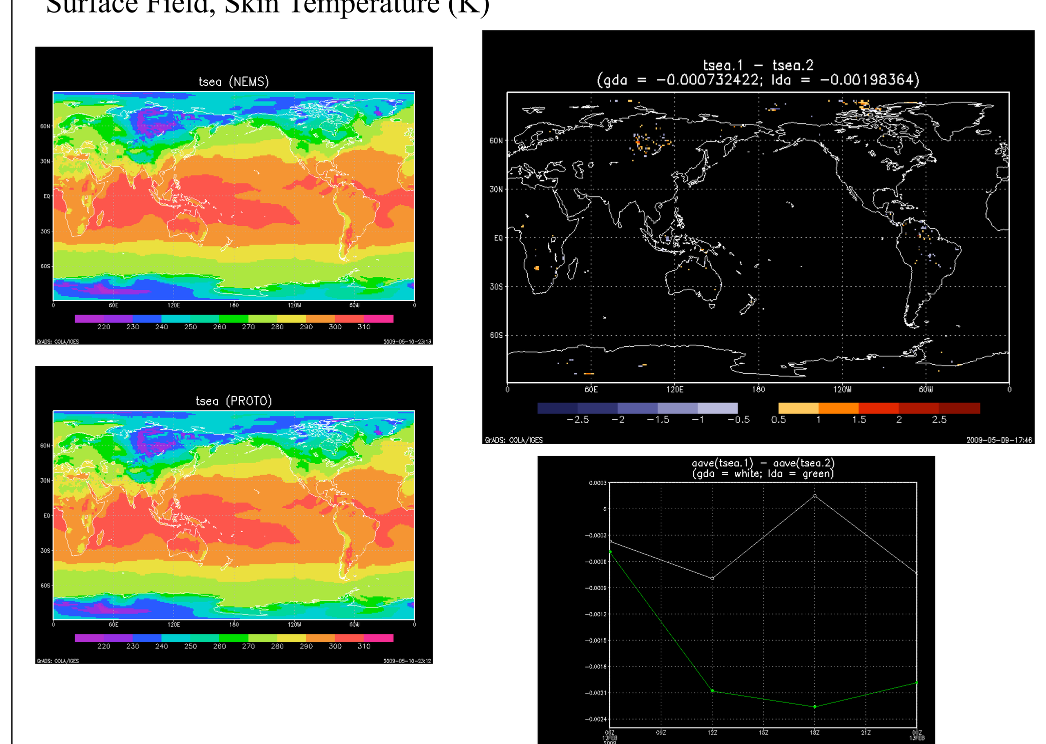
Noah Output Field, Latent Heat Flux (W/m^2)



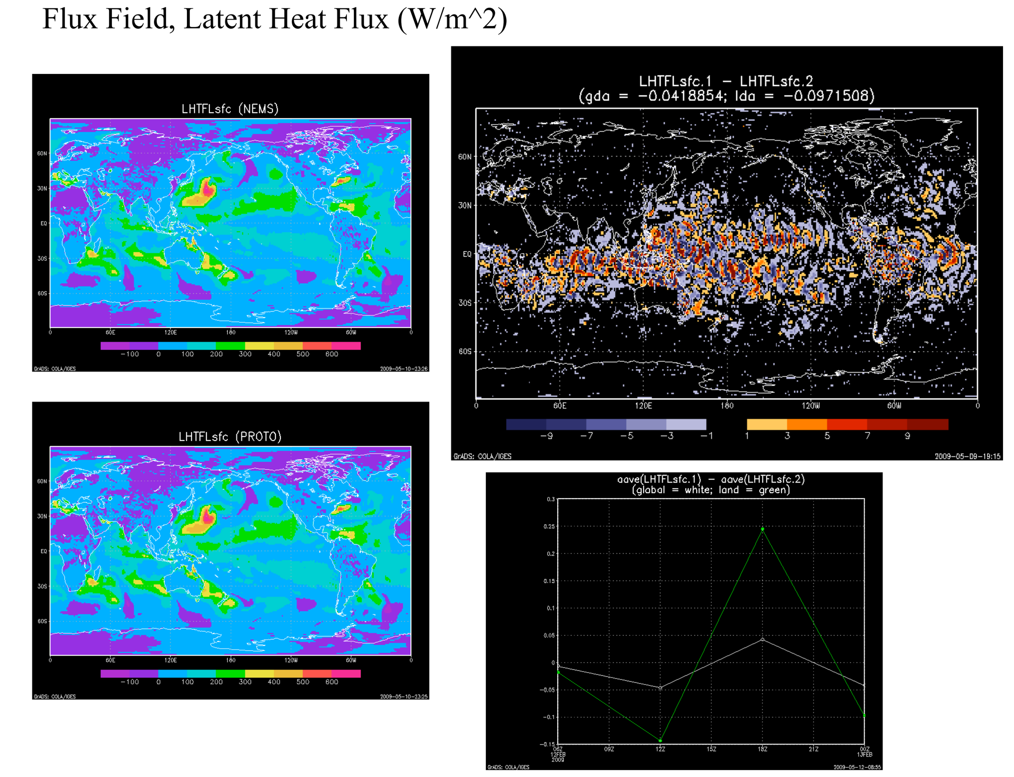
Benchmarks After 24-hour Simulation

The 24-hour forecast comparison from the two systems show promise, though there are differences in certain output variables (An example is shown below). These comparisons, however, do not show trends of systematic and monotonically growing errors present in the prototype system. Ongoing work is addressing these issues.

Surface Field, Skin Temperature (K)



Flux Field, Latent Heat Flux (W/m^2)



Conclusions and Future Work

A viable prototype for coupling LIS and NEMS has been developed. Among the accomplishments of this project are the identification and resolution of many low-level issues between LIS and NEMS; then implementation of a LIS-NEMS coupler, definition of import and export states; and the completion of the coupling support within LIS. In addition, an ESMF redistribution scheme has been developed, and work on refactoring NEMS is close to completion.

Continuing work will complete the refactoring of NEMS so that land, ocean, and sea-ice processes are separated from each other. This refactored version will allow us to resolve the remaining coupling issues within NEMS. This will also allow us to propagate ESMF grid information to lower levels within NEMS. Then the ESMF redistribution scheme can be implemented, providing a fully ESMF compliant coupler.

For more information, visit http://lis.gsfc.nasa.gov/,
or contact James Geiger (james.v.geiger@nasa.gov).