Overview of CISM Code Coupling
C. Goodrich and the CISM Coupling Team

Introduction
The Code Coupling Thrust is responsible for the developing and maintaining successive versions of the CISM comprehensive model, including:
- Defining our code coupling approach
- Selecting the computational science tools needed
- Applying these tools with our science codes to create the CISM comprehensive models

Coupling Requirements:
- Truly minimal code modification
- Efficient data transfer between codes
- Data translation (physics) and interpolation (grid)
- Control of independently executing codes

Model Coupling Approach

Generation 1
Code developers use Ad Hoc hardwired linkages
Test scientific validity and refine codes

Generation 2
Computational framework based on Object Oriented Programming (OOP) using existing packages
- Intelligent Data Channels, Program Control (InterComm)
- Data Manipulation and Interpolation (Overture)

Generation 3
Next generation framework to be developed in partnership with the Earth Systems Modeling Framework (ESMF) project

Generation 2 Framework

The CISM Comprehensive Models
The functionality of our comprehensive models come from two sources:
1. Strengths of the individual component codes
2. End to end coupling, which eliminates boundary conditions and other limitations of the individual codes

CISM 1.0 ...
Ad hoc coupling of the MAS, ENLIL, LFM, and TING codes
Following 1.x versions incorporate improved versions of these codes, additional codes, and the replacement of TING by TIE-GCM code

CISM 1.5 ...
Added Capabilities:
- Physical Inputs for ENLIL, LFM, and ITM
- Accurate Ionosphere F (Particle precipitation from LFM and Conductances from ITM)

CISM 2.0 ...
Added Capabilities:
- Expanded Observatory support (redundancy, verification)
- CME (Empirical) propagation (Cone Model)
  (shock strength and arrival time)
- Accurate description of inner Magnetosphere (pressure and magnetic field)

CISM 3.0 ...
Added Capabilities:
- 3rd Generation coupling
- Physical CME initiation (CME initiation from coronal active regions)
- Kinetic scale physics (MI coupling, reconnection, …)

Data Manipulation and Interpolation - Couplers:
Couplers make data from one code useful to another by:
- Interpolation between disparate grids
  - requiring knowledge of grid structures of all codes
- Conversion of data between disparate physical models
  - requiring knowledge of code data and conversion methods

Overture is a set of C++ classes providing:
- Interpolation between (moving, static) overlapping grids
- Powerful syntax for data manipulation including array arithmetic and (numerical) differential operations
- Registration and archiving of grids, coordinate mapping, and state variables in HDF database(s)
- Seamless interaction with IC (common data libraries)

CISM Geospace coupling in terms of our 2nd Generation Framework. The red arrows indicate data communication and the yellow oval indicates data manipulation.

Results of prototype Overture versions of the Magnetosphere-Ionosphere Coupler for the October 2003 Magnetic storm

Full S with $S_{2}=50$ mho
Full S with $E_{B} = 0$
LFM solution

Magnetic Storm Results Data

October 2003 Storm Data

18:55 UT

Next generation framework to be developed in partnership with the Earth Systems Modeling Framework (ESMF) project

Intelligent Data Channels and Program Control:
InterComm is a programming environment (API) and runtime library that provides functions for:
(www.cs.umd.edu/projects/hps/hps/ResearchAreas/ic/)
- Transferring data efficiently between programs
  - Direct (MxN) processor to processor transfer between parallel programs
  - Support for FORTRAN, C, and C++
- Controlling when data transfers occur
  - Nonblocking exports – IC caches data until it is requested
  - Codes export data (with timestamp) and keep going
  - Synchronization of execution through timestamps on data transfers
- Deploying multiple coupled programs
  - IC demons read config files – launch codes and set up data paths

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