Coupling an Alternate Land Surface Model (the ISAM) with the CESM

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Objectives

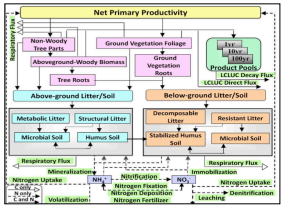
◆To expand our understanding of the terrestrial biogeophysical-biogeochemical processes and their interactions/feedbacks with the global climate system, we need:

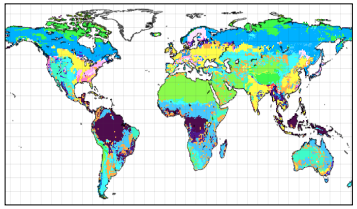
- ❖To investigate how the interactions among the climate, the biosphere, the ocean, and human activity can amplify or mitigate the pace of climate change

◆To achieve this scientific objective, a new Earth System Modeling (ESM) framework, comprised of the Integrated Science Assessment Model (ISAM) coupled with NCAR's Community Earth System Model (CESM), the **CESM-ISAM**, is currently being developed for application in global climate studies

- ❖The CESM-ISAM will provide a unique opportunity to compare its performance with the CESM-CLM4 and to identify areas of major disagreement. Through the analysis of the causes of the disagreements, we will gain a better understanding of the impact of alternative representations of terrestrial biogeochemistry formulations in climate feedbacks

Integrated Science Assessment Model (ISAM)





Tropical Evergreen
Tropical Deciduous
Temperate Evergreen
Temperate Deciduous
Boreal Forest
Savanna
Grassland
Shrub land
Tundra
Desert
Polar Desert
Cropland
Pastureland
Sec. Tropical Evergreen
Sec. Tropical Deciduous
Sec. Temperate Evergreen
Sec. Temperate Deciduous
Sec. Boreal Forest

◆A process-based **Land Surface Model** (LSM) [Spatial Resolution: **0.5ºx0.5º**; Time Step: **30 minutes**]

◆Detailed representation of terrestrial **biogeochemical** processes; includes prognostically coupled **Carbon-Nitrogen** (C-N) cycles, **Land Cover and Land Use Change** (LCLUC), and **Secondary Forest** Dynamics

◆**Biogeophysical** schemes in the ISAM adapted from the **CLM3.5/CLM4** and the **CoLM** (Common Land Model)

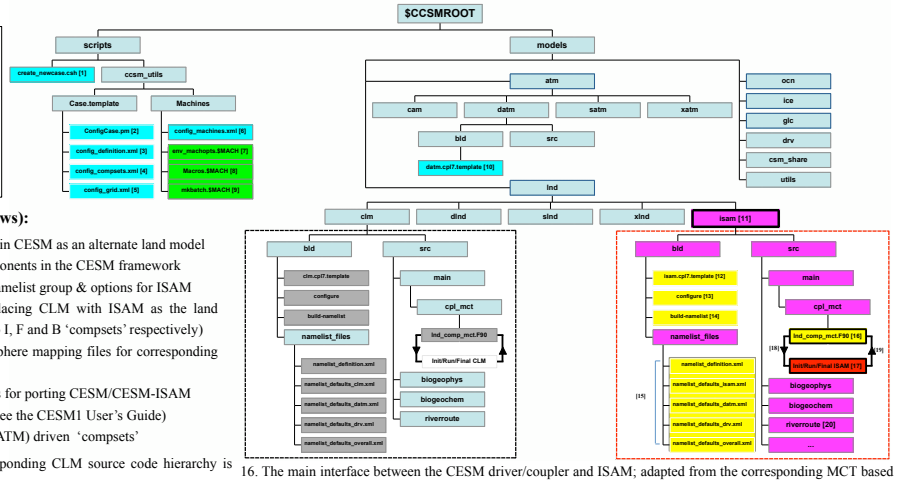
◆Further **modifications** in several key biogeophysical parameterizations (e.g., photosynthesis, LAI, dynamic roots, secondary forest regrowth, snow, natural fire regimes), and datasets (e.g., LCLUC)

◆The **CESM-ISAM** coupling extends ISAM's capabilities to study terrestrial biogeophysics-biogeochemistry interactions and associated regional and global climate feedbacks

CESM-ISAM Coupling Steps & Flowchart

Legends:

- CESM directory
- Modified CESM script for CESM-ISAM
- Added script to port to an unsupported machine
- Added ISAM directory
- Added ISAM script/Fortran file for CESM-ISAM
- CLM script/Fortran files
- ISAM routines (init/run/final) based on MCT



Notes (Corresponding to the numbered boxes/arrows):

1. Set ISAM path (**models/lnd/isam/bld/isam.cpl7.template**) in CESM as an alternate land model
2. Define ISAM as a new component with other existing components in the CESM framework
3. Add ISAM as an alternate land component; Define a new namelist group & options for ISAM
4. Define/Add new component sets and configurations, replacing CLM with ISAM as the land component (e.g., **I_isam, F_isam, B_isam** corresponding to I, F and B 'compsets' respectively)
5. Define/Add new ISAM grids (e.g., **0.5ºx0.5º**); Land-atmosphere mapping files for corresponding ISAM grids are generated offline using the **SCRIP** package
6. In an unsupported machine ($MACH), add machine settings for porting CESM/CESM-ISAM

7-9. Required files for porting to a new, unsupported machine (See the CESM1 User's Guide)

10. Add support for new ISAM grid(s) for atmospheric data (DATM) driven 'compsets'
11. ISAM land model root directory in CESM-ISAM (Corresponding CLM source code hierarchy is also shown in the flowchart for comparison with the ISAM counterpart)
12. Generates three required scripts for building ISAM in CESM-ISAM analogous to the three scripts generated for CLM (**isam.buildexe.csh, isam.buildnml.csh, isam.input_data_list**)
13. Add available paths ("**Filepath**") for ISAM source directories
14. Builds a land model namelist for the defined CESM configuration which contains CESM specific control parameters; ISAM specific namelist options are read using another namelist
15. Define and assign default values of the land model namelist options in CESM
16. The main interface between the CESM driver/coupler and ISAM; adapted from the corresponding MCT based CLM module (clm/src/main/cpl_mct/lnd_comp_mct.F90)
17. ISAM initialization/run/finalization methods; initializes **SPMD, global segmentation map, land Domain**; **imports** atmospheric inputs from the coupler to the land, **runs** the land model, and **exports** output back to the coupler

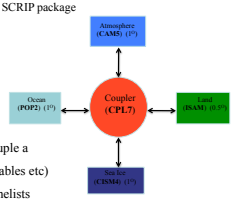
18-19. Fluxes/States from the coupler to the land, and from the land to the coupler, respectively

20. The **River Routing Model (RTM)**, extensively modified for ISAM data structures/grids from the original CLM version

Challenges of Coupling & Approach

◆**Scientific Challenges:**

- ❖Adding an alternate land model (the ISAM) in the CESM modeling framework
- ❖Replicating the functionality (fluxes & states) of the existing land model (CLM) as perceived by the CESM coupler/driver
- ❖Supporting a new land (ISAM) grid/resolution (e.g., 0.5ºx0.5º) in the CESM
  - ✓New land-atmosphere interpolation mappings required by the coupler are created using the SCRIP package
  - ✓The land mask should be a complement of the ocean mask
- ❖ISAM's coupling time step must be the same as that of atmospheric-physics time step
- ❖Adapting the functionality of the River Transport Model (RTM) for the ISAM



◆**Software Challenges:**

- ❖Preserving the existing and available CESM configurations and setups
- ❖Adapting from the existing CLM codes to replicate common functionalities required to couple a new land model into the CESM framework (e.g., IO, time management structure, restart variables etc)
- ❖Aligning ISAM's 'Control' variables, for compatibility with the CESM driver & CLM namelists
- ❖Ensuring compatibility with future version updates of the CESM

◆**Approach to Coupling:**

- ❖**Develop a more generic coupler-land interface and utilities** for coupling a new land model into the CESM framework, which may be of interest to other modeling groups
- ❖**Incrementally test the coupled CESM-ISAM framework**:
  - ✓First, run the ISAM within the CESM driven by the Data Atmosphere Model, DATM (CESM-ISAM compset 'I_isam', analogous to CESM compset 'I') to carefully diagnose the ISAM state/flux variables required by the CESM coupler for fully prognostic land-atmosphere coupling
  - ✓Having ensured consistency of the fluxes/states, run prognostic land-atmosphere simulations (CESM-ISAM compset 'F_isam')
  - ✓ Finally, run the fully coupled land-atmosphere-ocean configurations (CESM-ISAM compset 'B_isam')

◆**Approximate Time Taken** for the coupling effort ~ 1.5 years

Where we are now…

◆The CESM-ISAM framework is currently (Summer, 2011) being tested on the **ORNL Jaguar** supercomputer, in collaboration with Mr. Forrest Hoffman (ORNL)

◆During the first test phase, comparisons of performances between CESM-ISAM and CESM-CLM4 will be attempted using observed, historical atmospheric data (NCAR-NCEP reanalysis data, through the DATM)

Proposed Experimental Setups

◆**Retrospective offline simulations (1948-2004)**: Using the ISAM; NCAR-NCEP reanalysis data; different sets of inter-annually varying observations (LCLUC, atmospheric CO_2 concentration, N deposition, etc); Spin-up: biogeophysics ~ 200 to 400 years, biogeochemistry ~ 30000 years, using a historical (~1951-1970) mean climatology in a multi-phase workflow (please **note**: *our methodology is different from CLM's Accelerated Decomposition Technique*); Perform extensive evaluation of ISAM's performance with various observational data

◆**Prognostic transient simulations (1900-2100)**: Ensembles based on RCP storylines; Spin-up: using the established IPCC protocols; ISAM will be additionally spun-up before importing into the CESM-ISAM framework

◆Corresponding CESM-ISAM and CESM-CLM runs will be used to study the impacts of different land surface parameterizations and their associated climate feedbacks

Some Suggestions for Improvement of the CESM Framework

◆Currently, the CESM framework can compile only one model from each component at a time (e.g., CLM and ISAM cannot run simultaneously); Support compiling/running for multiple models from the same component will produce a easier coupling framework, and have important applications for multi-model ensembles & comparisons

◆The River Transport Model, currently embedded into the CLM should be treated as an independent CESM component, and coupled through the CESM coupler

Future Challenges…

◆Advancing computational performance (load balancing, scalability) of the CESM-ISAM framework on current and future computing architectures, in collaboration with Dr. Sanjay Kale (UIUC)

- ❖By **integrating advanced load balancing algorithms** using **Charm++/Adaptive-MPI** (AMPI) systems; **AMPI** employs migratable objects, enabling the creation of a powerful infrastructure for dynamic load balancing and enhanced scalability
- ❖By **accessing the current load balancing practice** in CESM/CESM-ISAM and its limitations, and subsequently evaluating the new/proposed **Charm++/AMPI** load balancers on the **Blue Waters machine** (which will be deployed at the University of Illinois at Urbana Champaign by December, 2011)

Conclusions

◆This research will add to a greater understanding of how to improve the representation of terrestrial C-N biogeochemistry in the LSMs, and will contribute to continued model development for the CESM

◆This CESM-ISAM coupling effort is likely to be of interest to modeling communities interested in coupling their respective models into the CESM framework

◆Successful demonstration of advanced load balancing tools (using AMPI) into ESM frameworks will be extremely beneficial for performing more computationally intensive ESM experiments in the future