Coupling an Alternate Land Surface Model with the Community Earth System Model (CESM1) through the Flux Coupler

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Objectives

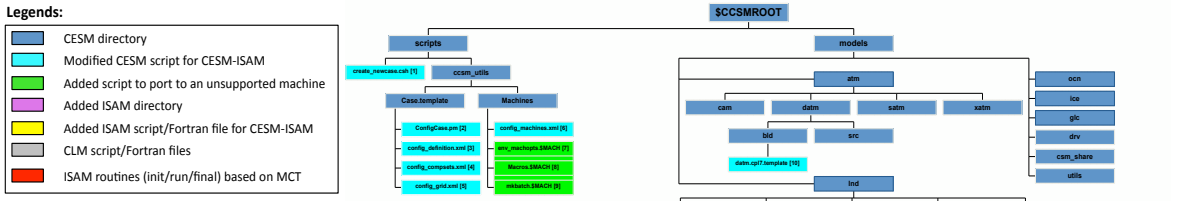
◆ To expand understanding of the **terrestrial biogeophysical-biogeochemical** processes and their **interactions with the global climate system**:

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

◆ To develop an Earth System Modeling framework, comprised of the **Integrated Science Assessment Model** (ISAM) coupled with NCAR's **Community Earth System Model** (CESM), the **CESM-ISAM**

- ❖ Compare performance of **CESM-ISAM** with the **CESM-CLM4** and to identify areas of major disagreement.
- ❖ Gain a **better understanding** of the **impact of alternative representations** of terrestrial biogeochemistry formulations in climate feedbacks

ISAM-CESM Coupling



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

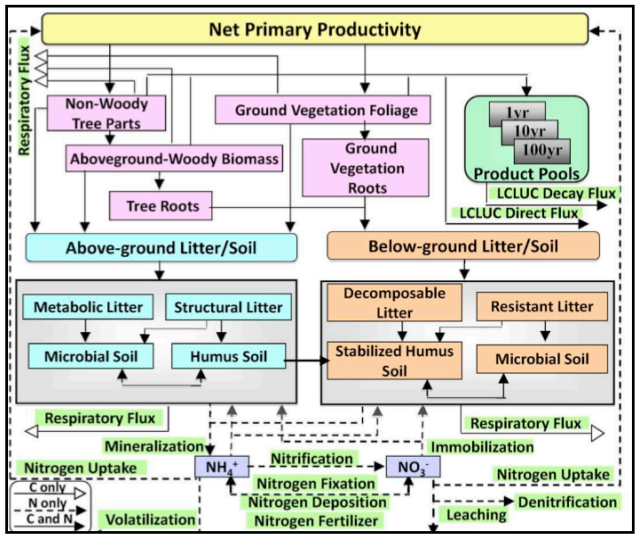
7-9. Required files for porting to a new, unsupported machine (See the CESM1 User's Guide)

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

Integrated Science Assessment Model



◆ **Land Surface Model**

- ❖ Spatial Resolution:0.5ºx0.5º
- ❖ Biogeophysics Time step: 30 minutes
- ❖ Biogeochemistry Timestep: 1 Week

◆ **Biogeochemical** processes

- ❖ Coupled **Carbon-Nitrogen** cycles,
- ❖ **Land Cover and Land Use Change**
- ❖ **Secondary Forest** Dynamics

◆ **Biogeophysical** schemes:

- ❖ Adapted from the **CLM3.5/CLM4** and the **CoLM**
- ❖ Further **modifications** in biogeophysics

◆ **CESM-ISAM:**

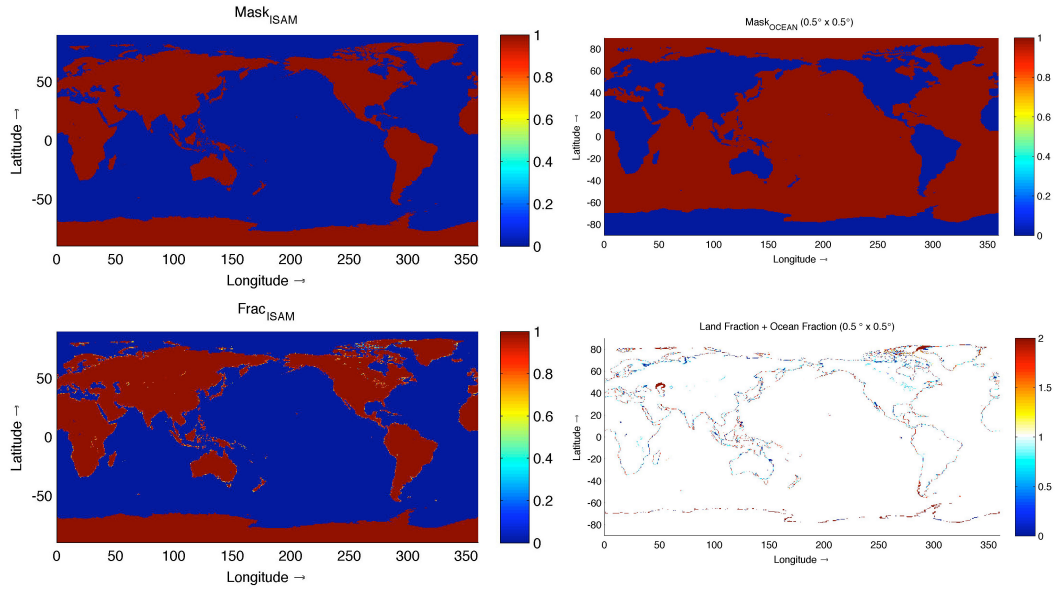
- ❖ Extends ISAM's capabilities to study terrestrial biogeophysics-biogeochemistry interactions and associated regional and global climate feedbacks

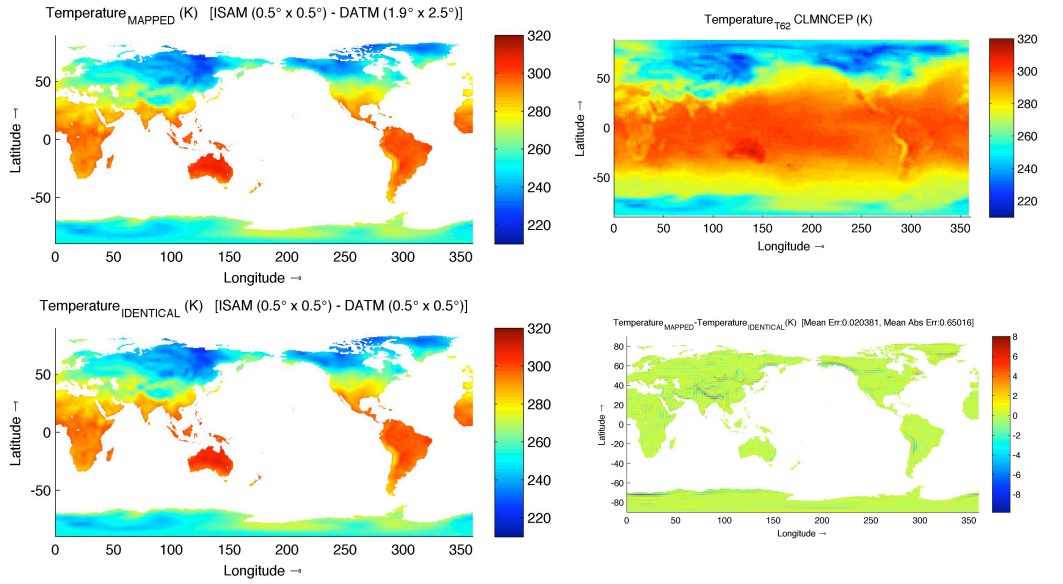
◆Scientific Challenges:

- ❖ 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





◆Scientific Questions:

❖ Sensitivity of the Carbon and Nitrogen fluxes to the recently improved representation of biogeophysics for the Northern high-latitudes:

✓ *How do they respond to the concurrent effects of climate change, CO_2 increase, Nitrogen deposition, and Land Use Change, during the historical period (e.g., 1980-2005)?*

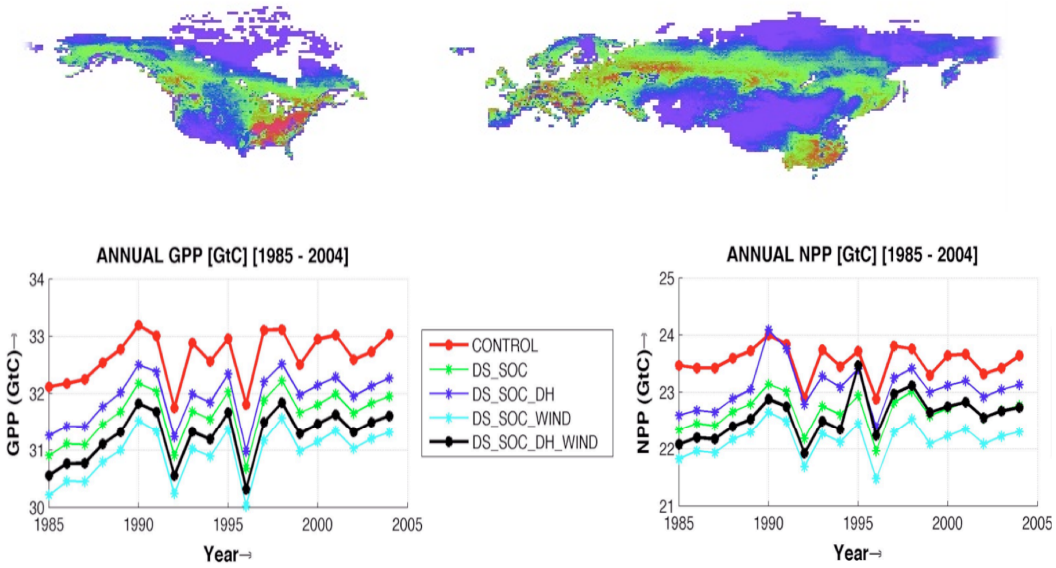
✓ *Using the improved ISAM, what was the net effect (radiative forcing) of the biogeophysical - biogeochemical feedbacks in the terrestrial high-latitude ecosystems to the climate during 1980-2005?*

❖ Northern high-latitude Permafrost Stability:

✓ *How do the improved biogeophysical and biogeochemical representations impact the stability of the permafrost compared to previous studies (such as Lawrence et al., 2008)?*

❖ Coupled CESM-ISAM modeling experiments to evaluate the permafrost and terrestrial carbon cycle feedback

✓ *Comparison of CESM-ISAM vs. "equivalent" CESM-CLM simulations*



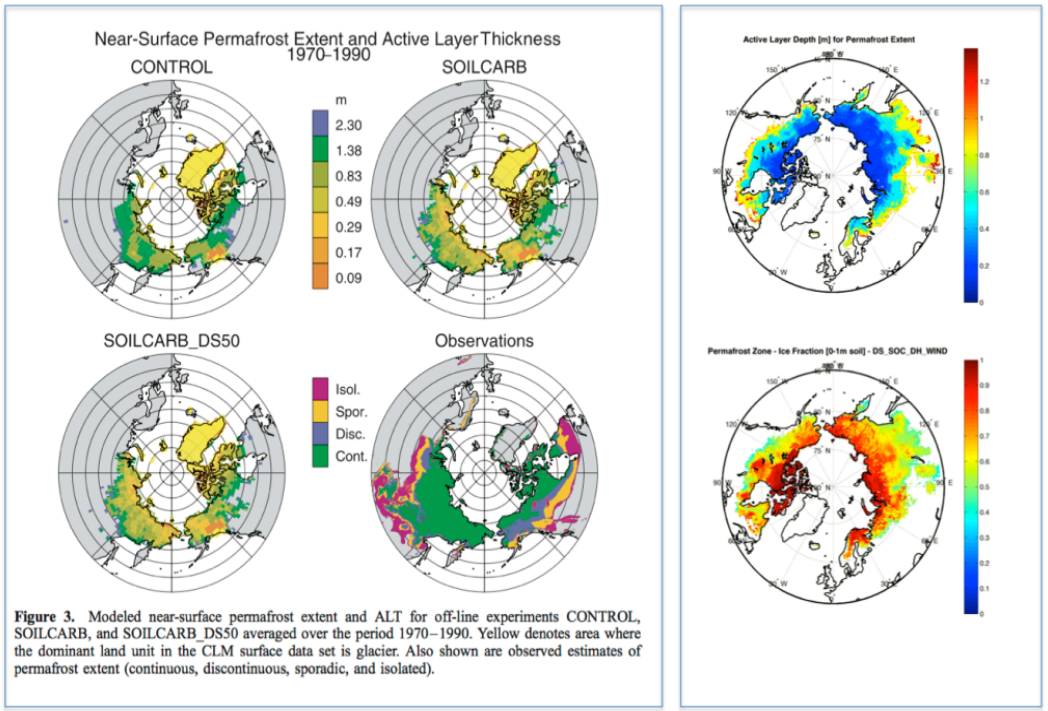


Figure 3. Modeled near-surface permafrost extent and ALT for off-line experiments CONTROL, SOILCARB, and SOILCARB_DS50 averaged over the period 1970–1990. Yellow denotes area where the dominant land unit in the CLM surface data set is glacier. Also shown are observed estimates of permafrost extent (continuous, discontinuous, sporadic, and isolated).