SIMA/CCPP update

2025 CESM workshop

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June 10, 2025

Talk outline

Talk outline

- Pretty pictures

Talk outline

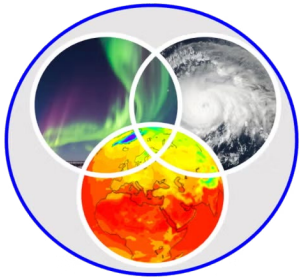
- Pretty pictures
- Important stuff

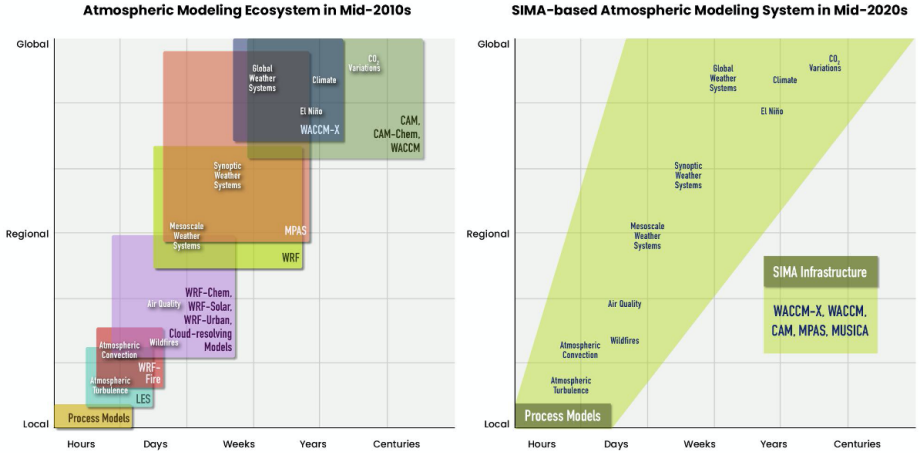
Talk outline

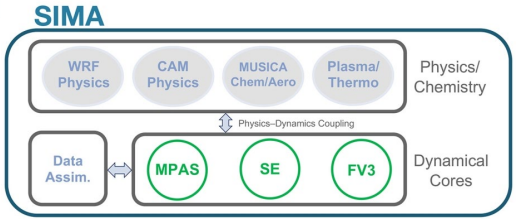
- Pretty pictures
- Important stuff
- Pretty animation

CAM-SIMA science goals

The System for Integrated Modeling of the Atmosphere (SIMA) is an attempt to expand CAM's capabilities, and create a unified modeling infrastructure for all global modeling (weather, climate, chemistry, geospace) modeling at NCAR.







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- What is the current status?

CAM-SIMA current status

- Working on modifying CAM4, CAM7, and MMM physics schemes to be CCPP-compliant (and work in CAM-SIMA).
- Also bringing in MUSICA capabilities (MICM and TUV-x) into CAM-SIMA.
- Hope to have a “real” CAM4 simulation running by end of fiscal year, with a “real” CAM7 simulation running ~6 months after that.
- But this is a software engineering talk, so has CAM-SIMA accomplished any software engineerings?

SIMA developments - Model configuration

Creating the configure object in CAM:

```
my $cfg = Build::Config->new($opts{'config'});
```

Creating the configure object in SIMA:

```
config = ConfigCAM(case, _LOGGER)
```

CAM uses ~8000 lines of Perl code in various scripts to properly configure the model and perform sanity checks. This has been entirely replaced with python code in CAM-SIMA, which provides several advantages, including:

1. Better integration with CIME.
2. More easily understood by users/developers.
3. More thorough testing.

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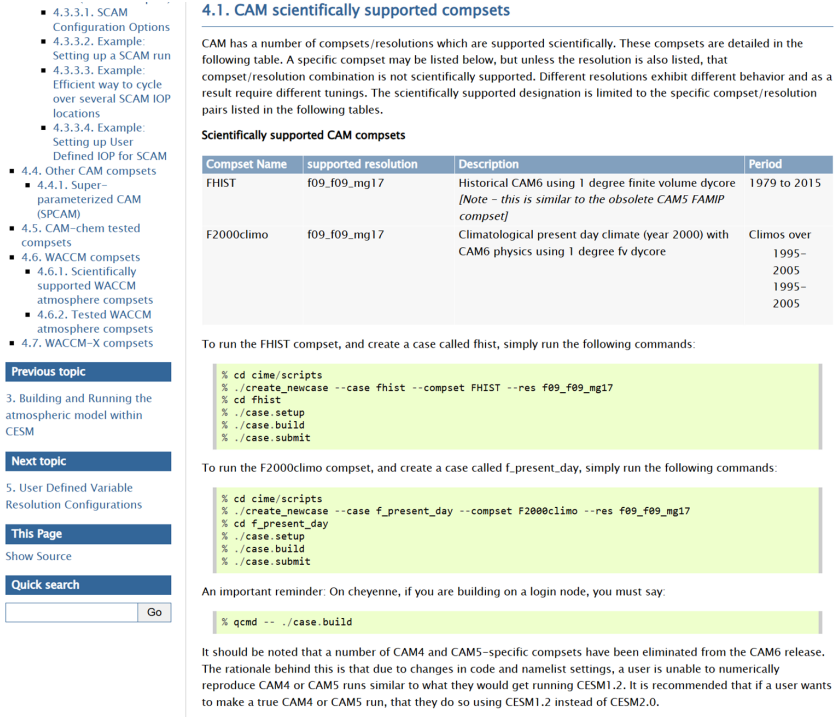
- User's guide



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3. Building and Running the atmospheric model within CESM

Next topic

5. User Defined Variable Resolution Configurations

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4.1. CAM scientifically supported compsets

CAM has a number of compsets/resolutions which are supported scientifically. These compsets are detailed in the following table. A specific compset may be listed below, but unless the resolution is also listed, that compset/resolution combination is not scientifically supported. Different resolutions exhibit different behavior and as a result require different tunings. The scientifically supported designation is limited to the specific compset/resolution pairs listed in the following tables.

Scientifically supported CAM compsets

Compset Name	supported resolution	Description	Period
FHIST	f09_f09_mg17	Historical CAM6 using 1 degree finite volume dycore *[Note – this is similar to the obsolete CAM5 FAMIP compset]*	1979 to 2015
F2000climo	f09_f09_mg17	Climatological present day climate (year 2000) with CAM6 physics using 1 degree fv dycore	Climos over 1995–2005 1995–2005

To run the FHIST compset, and create a case called fhist, simply run the following commands:

```
% cd cime/scripts
% ./create_newcase --case fhist --compset FHIST --res f09_f09_mg17
% cd fhist
% ./case.setup
% ./case.build
% ./case.submit
```

To run the F2000climo compset, and create a case called f_present_day, simply run the following commands:

```
% cd cime/scripts
% ./create_newcase --case f_present_day --compset F2000climo --res f09_f09_mg17
% cd f_present_day
% ./case.setup
% ./case.build
% ./case.submit
```

An important reminder: On cheyenne, if you are building on a login node, you must say:

```
% qcmd -- ./case.build
```

It should be noted that a number of CAM4 and CAM5-specific compsets have been eliminated from the CAM6 release. The rationale behind this is that due to changes in code and namelist settings, a user is unable to numerically reproduce CAM4 or CAM5 runs similar to what they would get running CESM1.2. It is recommended that if a user wants to make a true CAM4 or CAM5 run, that they do so using CESM1.2 instead of CESM2.0.

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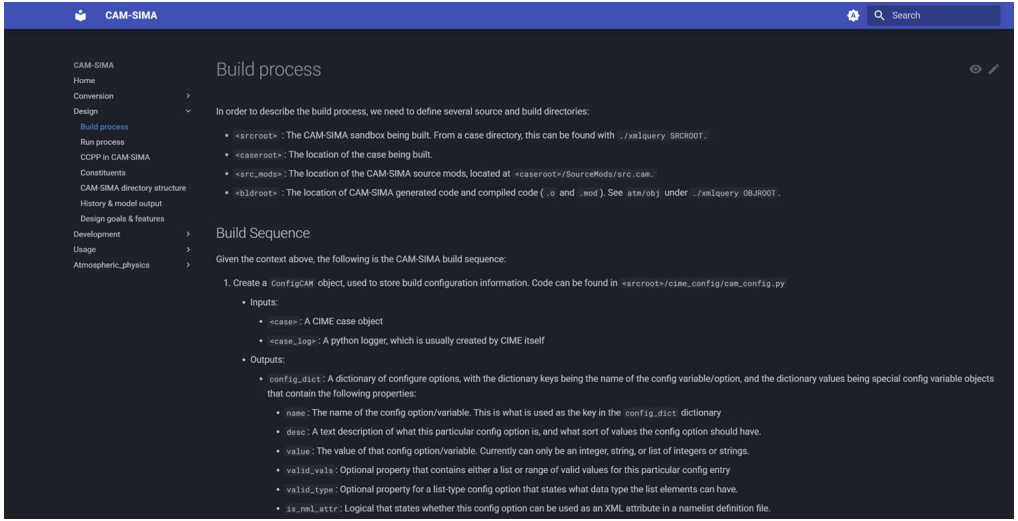

*Thanks to Courtney Peverley and Michael Waxmonsky

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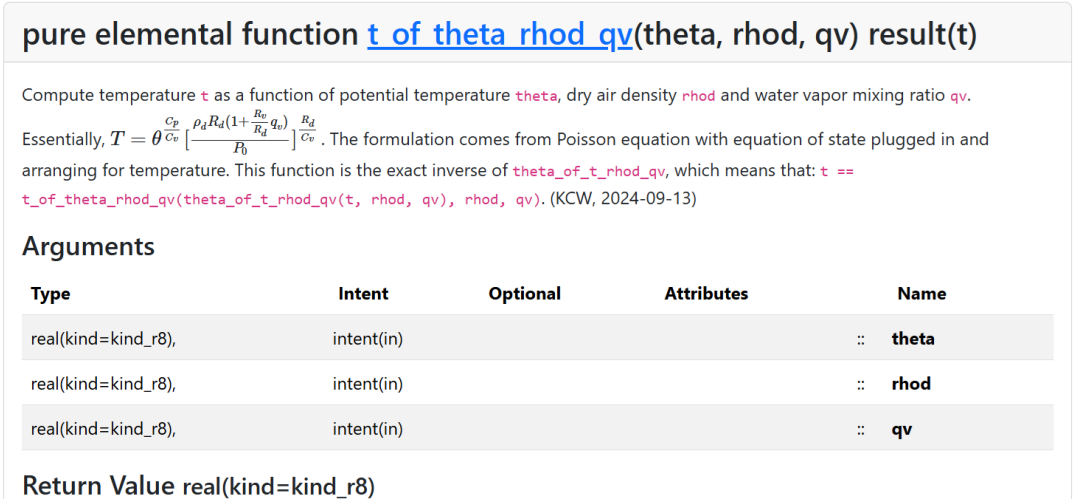
- User's guide
- Developer's guide
- Scientific documentation



pure elemental function t_of_theta_rhod_qv(theta, rhod, qv) result(t)

Compute temperature `t` as a function of potential temperature `theta`, dry air density `rhod` and water vapor mixing ratio `qv`. Essentially, $T = \theta^{\frac{C_p}{C_v}} \left[\frac{\rho_d R_d (1+\frac{R_v}{R_d} q_v)}{P_0}\right]^{\frac{R_d}{C_v}}$. The formulation comes from Poisson equation with equation of state plugged in and arranging for temperature. This function is the exact inverse of `theta_of_t_rhod_qv`, which means that: `t == t_of_theta_rhod_qv(theta_of_t_rhod_qv(t, rhod, qv), rhod, qv)`. (KCW, 2024-09-13)

Arguments

Type	Intent	Optional	Attributes		Name
real(kind=kind_r8),	intent(in)			::	**theta**
real(kind=kind_r8),	intent(in)			::	**rhod**
real(kind=kind_r8),	intent(in)			::	**qv**

Return Value real(kind=kind_r8)

*Thanks to Kuan-Chih Wang

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- User's guide
- Developer's guide
- Scientific documentation

```
pure elemental function calc_friction_velocity(taux, tauy, rrho) result(friction_velocity)
    ! https://glossary.ametsoc.org/wiki/Friction_velocity
    ! NOTE: taux,tauy come form the expansion of the Reynolds stress
    !
    ! Also found in:
    ! Stull, Roland B. An Introduction to Boundary Layer Meteorology. Springer Kluwer Acade
    ! DOI: https://doi.org/10.1007/978-94-009-3027-8
    ! Equation 2.10b, page 67
```

*Thanks to Michael Waxmonsky

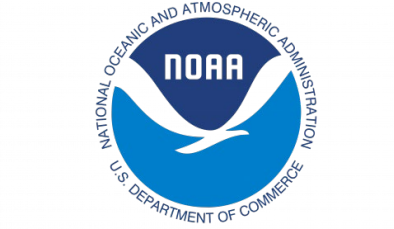
SIMA developments - testing

An improvement upon CAM is that CAM-SIMA has unit testing which is run automatically via Github Actions, these currently include:

- Python unit tests
- Python linting (pylint)
- Fortran unit tests

SIMA developments - CCPP

The Common Community Physics Package (CCPP) is a multi-agency effort to try and create portable and inter-operable physics schemes for use across various weather, climate, and earth system models.



SIMA developments - modularity

Original CAM scheme contains host-model specific features.

```
subroutine rayleigh_friction_tend(                                  &
   ztodt    ,state    ,ptend    )

   !-----------------------------------------------------------------------
   ! compute tendencies for rayleigh friction
   !-----------------------------------------------------------------------
   use physics_types, only: physics_state, physics_ptend, physics_ptend_init

   !-----------------------------Arguments---------------------------------
   real(r8),            intent(in) :: ztodt      ! physics timestep
   type(physics_state), intent(in) :: state      ! physics state variables

   type(physics_ptend), intent(out):: ptend      ! individual parameterization tendencies
```

CCPP-ized scheme contains no model-specific “use” statements or DDTs/objects

```
!===============================================================================
!> \section arg_table_rayleigh_friction_run Argument Table
!! \htmlinclude rayleigh_friction_run.html
subroutine rayleigh_friction_run(pver, ztodt, u, v, dudt, dvdt, dsdt, errmsg, errflg)

  !-----------------------------Arguments---------------------------------
  integer,             intent(in) :: pver
  real(kind_phys),     intent(in) :: ztodt   !physics timestep
  real(kind_phys),     intent(in) :: u(:,:)
  real(kind_phys),     intent(in) :: v(:,:)
  real(kind_phys),    intent(out) :: dudt(:,:) !tendency_of_eastward_wind
  real(kind_phys),    intent(out) :: dvdt(:,:) !tendency_of_northward_wind
  real(kind_phys),    intent(out) :: dsdt(:,:)  !heating_rate

  character(len=512), intent(out) :: errmsg
  integer,            intent(out) :: errflg
```

SIMA developments - configurability

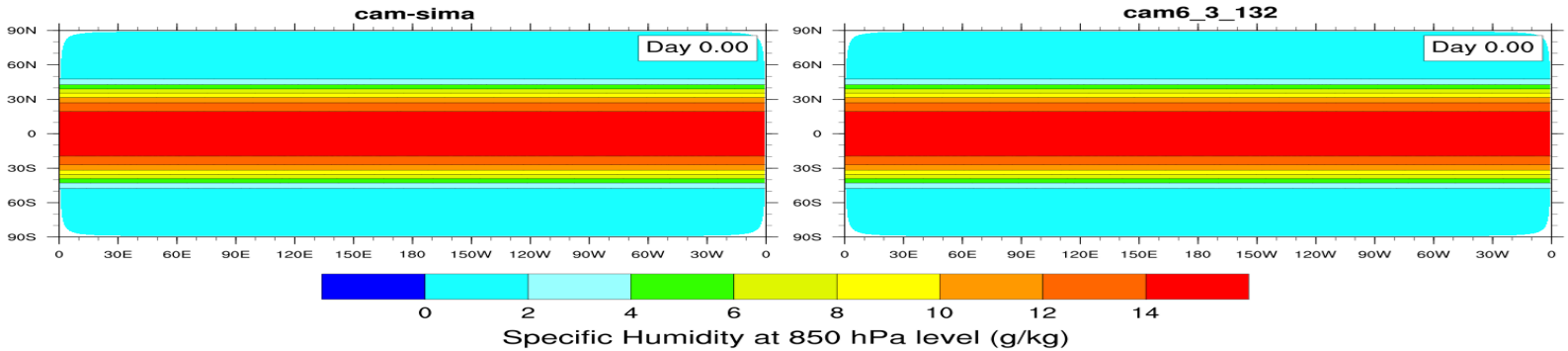
The CCPP allows a CAM-SIMA user to easily change the order or create new combinations of physics schemes, called “suites”.

CAM-SIMA also has the ability to change the number of vertical levels and tracers at runtime, which CAM currently cannot do without a rebuild. This also means CAM-SIMA will eventually have runtime chemistry configurability as well.

```xml
<?xml version="1.0" encoding="UTF-8"?>

<suite name="held_suarez_1994" version="1.0">
  <group name="physics_before_coupler">
    <scheme>held_suarez_1994</scheme>
    <scheme>apply_tendency_of_eastward_wind</scheme>
    <scheme>apply_tendency_of_northward_wind</scheme>
    <scheme>apply_heating_rate</scheme>
    <scheme>geopotential_temp</scheme>
    <scheme>sima_state_diagnostics</scheme>
  </group>
  <group name="physics_after_coupler">
    <scheme>sima_tend_diagnostics</scheme>
  </group>
</suite>
```

Idealized physics results - moist baroclinic wave



*Thanks to Adam Herrington

Thanks for listening!

Questions?