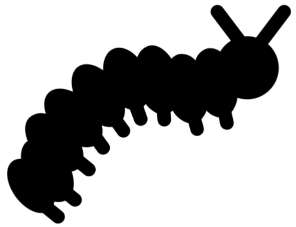
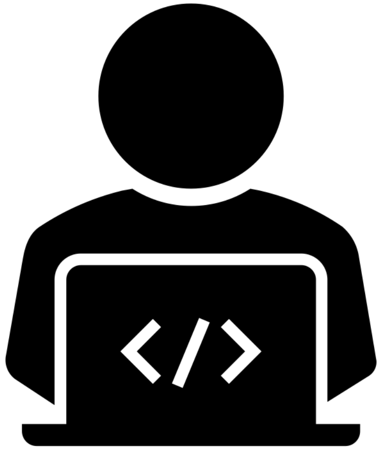
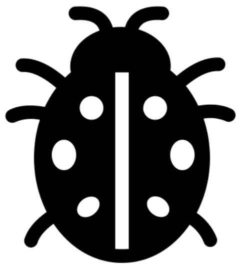
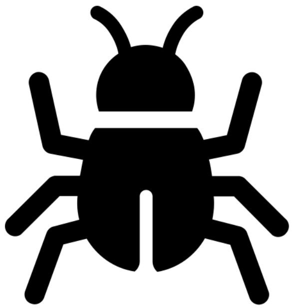






Debugging E3SM Atmosphere Model

A new tool inspired by Perturbation growth test method



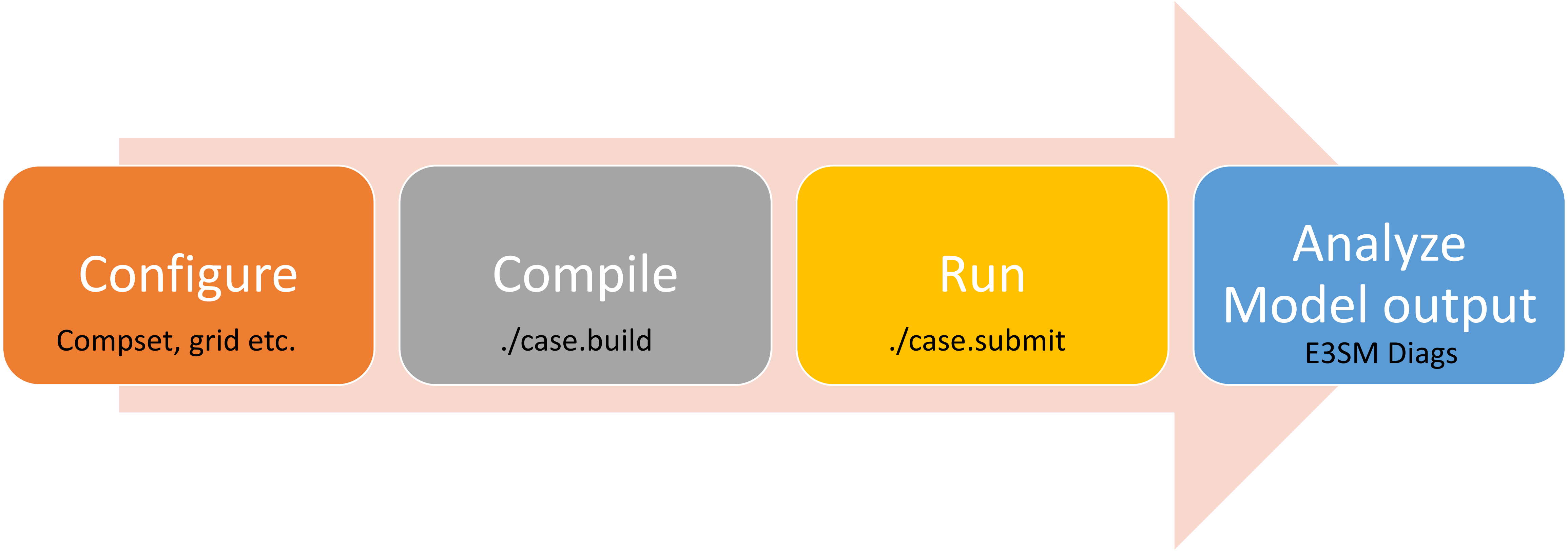
Balwinder Singh, Phil Rasch and Hui Wan

"The most secure code is the code that is never written" – Colin Percival

Outline

- Classes of model errors
- Reasons E3SM like codes are harder to debug
- Commonly used debugging tools
- EAM’s Inbuilt debugging tools
- Test cases

Typical Workflow

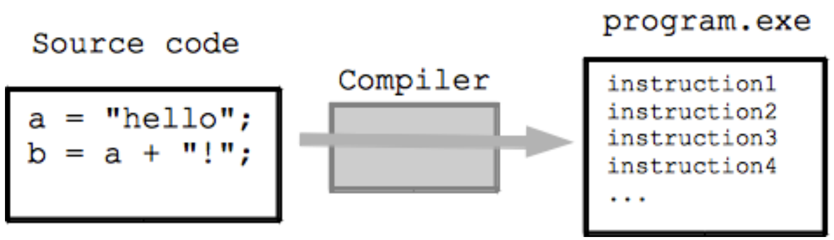


Classes of Model Errors

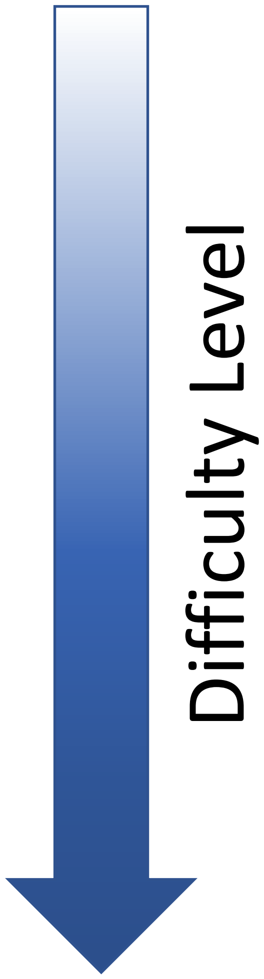
- Configure issues:

```
ERROR: Command: 'components/cam/bld/configure -s -ccsm_seq -ice none -ocn docn -comp_intf mct -dyn se -
dyn_target preqx -res ne4np4 -phys cam5 -clubb_sgs -microphys mg2 -chem linoz_mam5_resus_mom -
rain_evap_to_coarse_aero -nlev 72 ' failed with error 'tar: Buildconf/camconf/chem_proc/cam.subs.tar:
Cannot open: No such file or directory
tar: Error is not recoverable: exiting now
```

- Compile time errors:




```
qfs/people/sing201/eagles/giant_mode/E3SM/components/cam/src/chemistry/modal_aero/dust_model.F90(12):
error #6404: This name does not have a type, and must have an explicit type.   [DUST_NAMES]
public :: dust_names
```

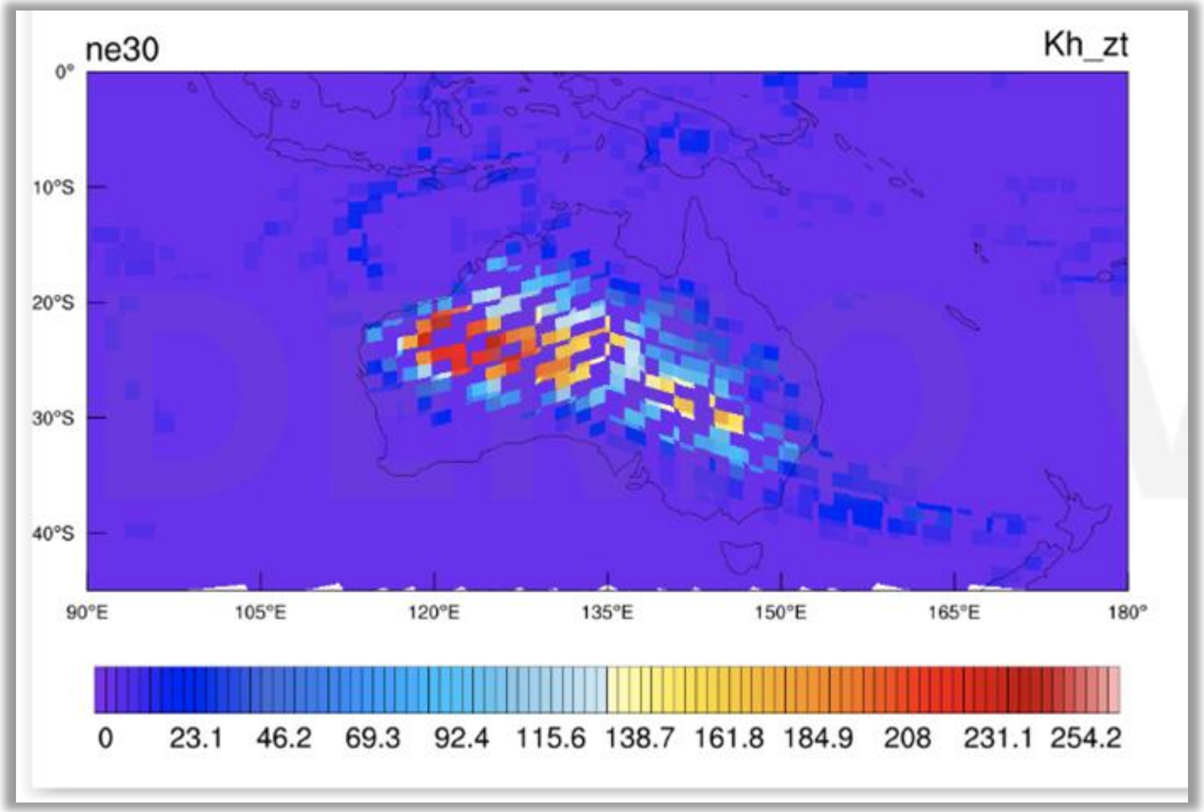


Classes of Model Errors

- Runtime errors:

```
1: Image            PC Routine               Line Source
1: e3sm.exe         0000000009A5520A Unknown             Unknown Unknown
1: e3sm.exe         00000000091B95F8 shr_abort_mod_mp_       114 shr_abort_mod.F90
1: e3sm.exe         00000000091B93E3 shr_abort_mod_mp_        61 shr_abort_mod.F90
1: e3sm.exe         0000000000AABD59 cam_abortutils_mp        59 cam_abortutils.F90
1: e3sm.exe         00000000027B25D7 rad_constituentsp      1653 rad_constituents.F90
```

- Wrong answers!

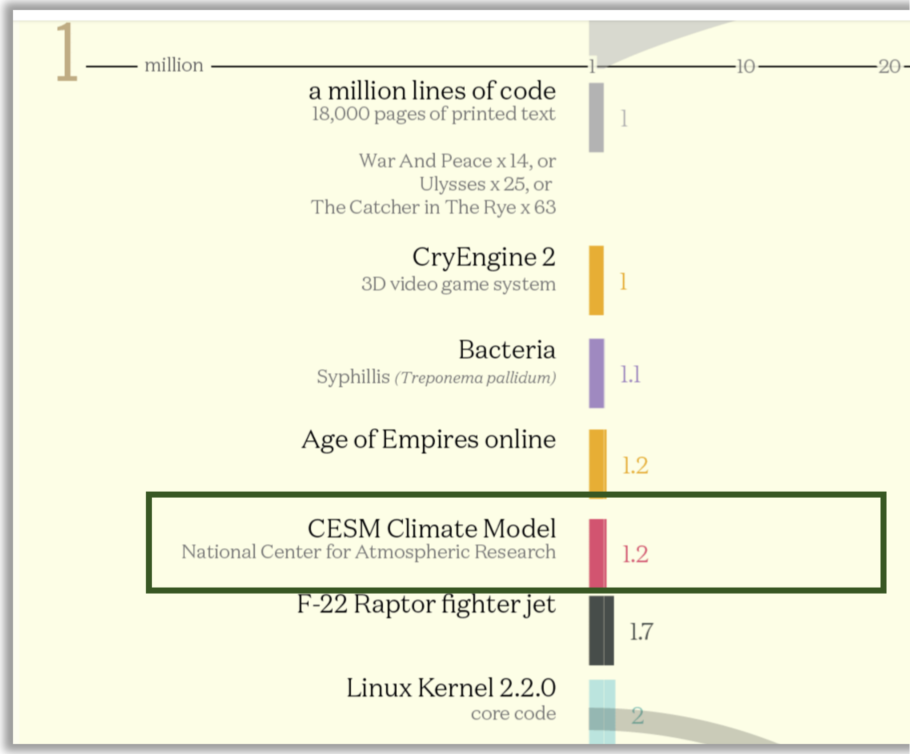


Difficulty Level

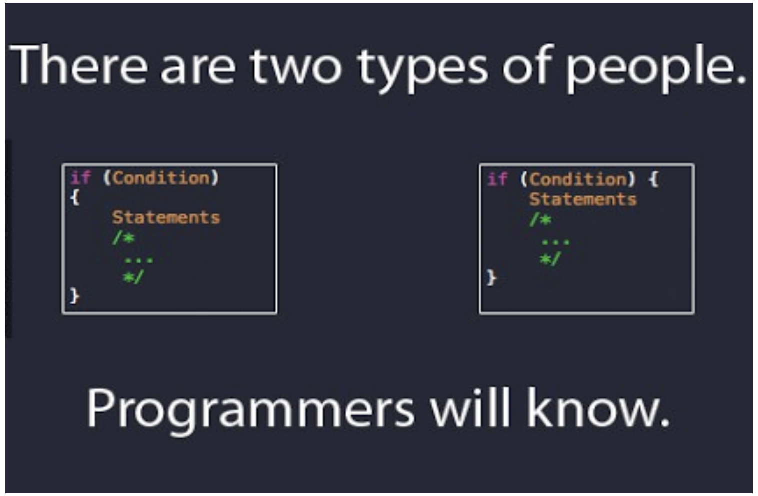
Why E3SM is harder to debug?

Parallel nature of the code

Size of the code

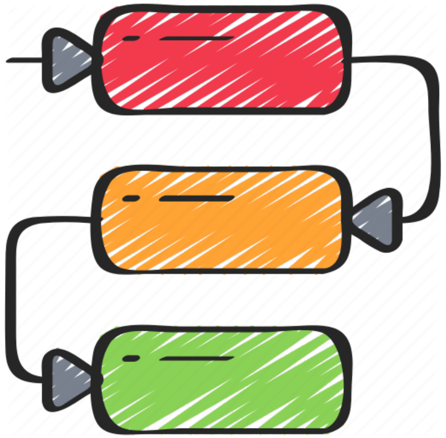


*E3SM branched off from CESM



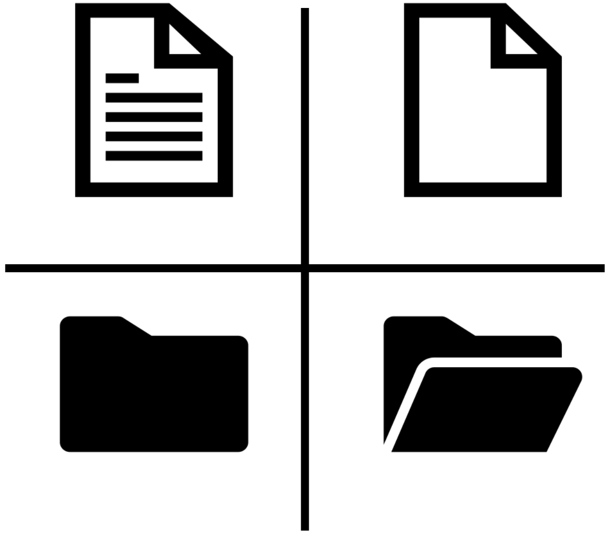
Different coding styles

Why E3SM is harder to debug?



Lots of dependencies

Scattered error log files



Configurable in many ways

"It works on my machine" -- Anonymous ☺

Common Debugging Tools

Good old print statements

```
Write(*,*) 'Temperature after rad:',state%t(i,k)
```

Debuggers/Compilers

“If you lie to a compiler, it will get its revenge” -- Henry Spencer

Opensource Debuggers

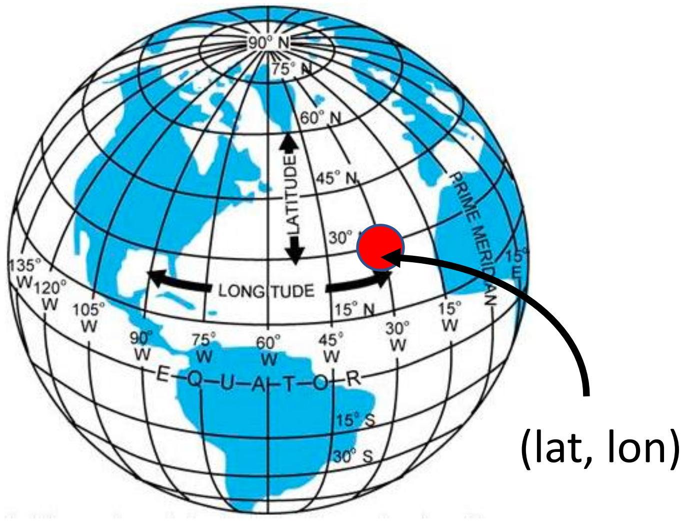
GDB

The GNU Project Debugger

Inbuilt Debugging Tools

Physics Debug Codes:

- Allows to focus on one grid point (lat, lon) on the globe



PERGRO Driven debugging:

- Allows to track how a physical process impacts state variables
- Uses **Physics Debug Codes** to find the offending line of code

Physics Debug Tools

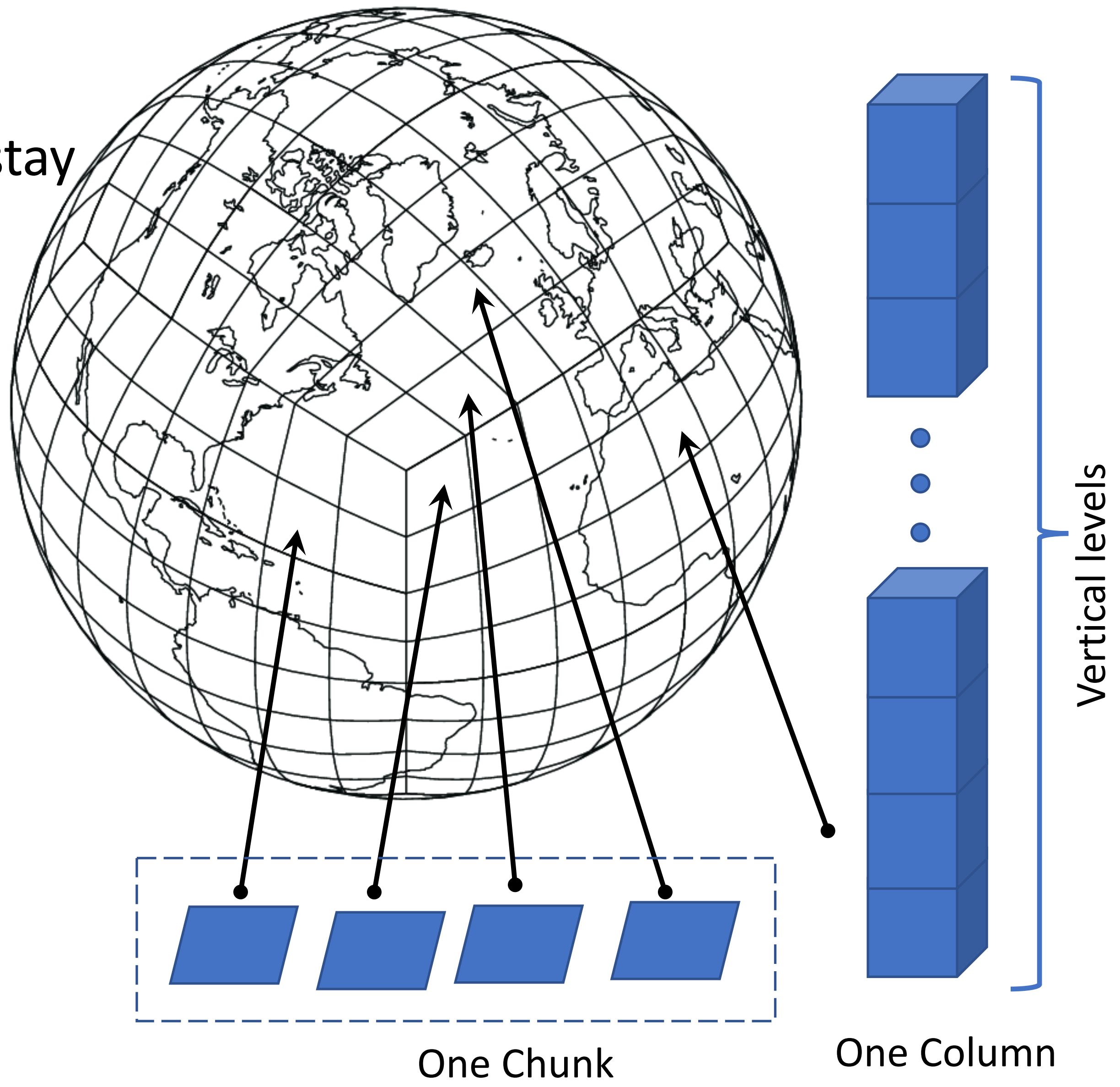
- Why this tool is very critical?
  - Parallel code – Chunks and columns
  - Indices of a variable can not be trusted to stay the same
- Allows us to identify a latitude and longitude combination in a model run using chunk
- Namelist changes:

```
phys_debug_lat=67.50000
phys_debug_lon=28.70000
```

- Inside EAM source code:

```
icol = phys_debug_col(chnk_id)
if(icol>0)write(*,*) 'taux', taux(icol)
```

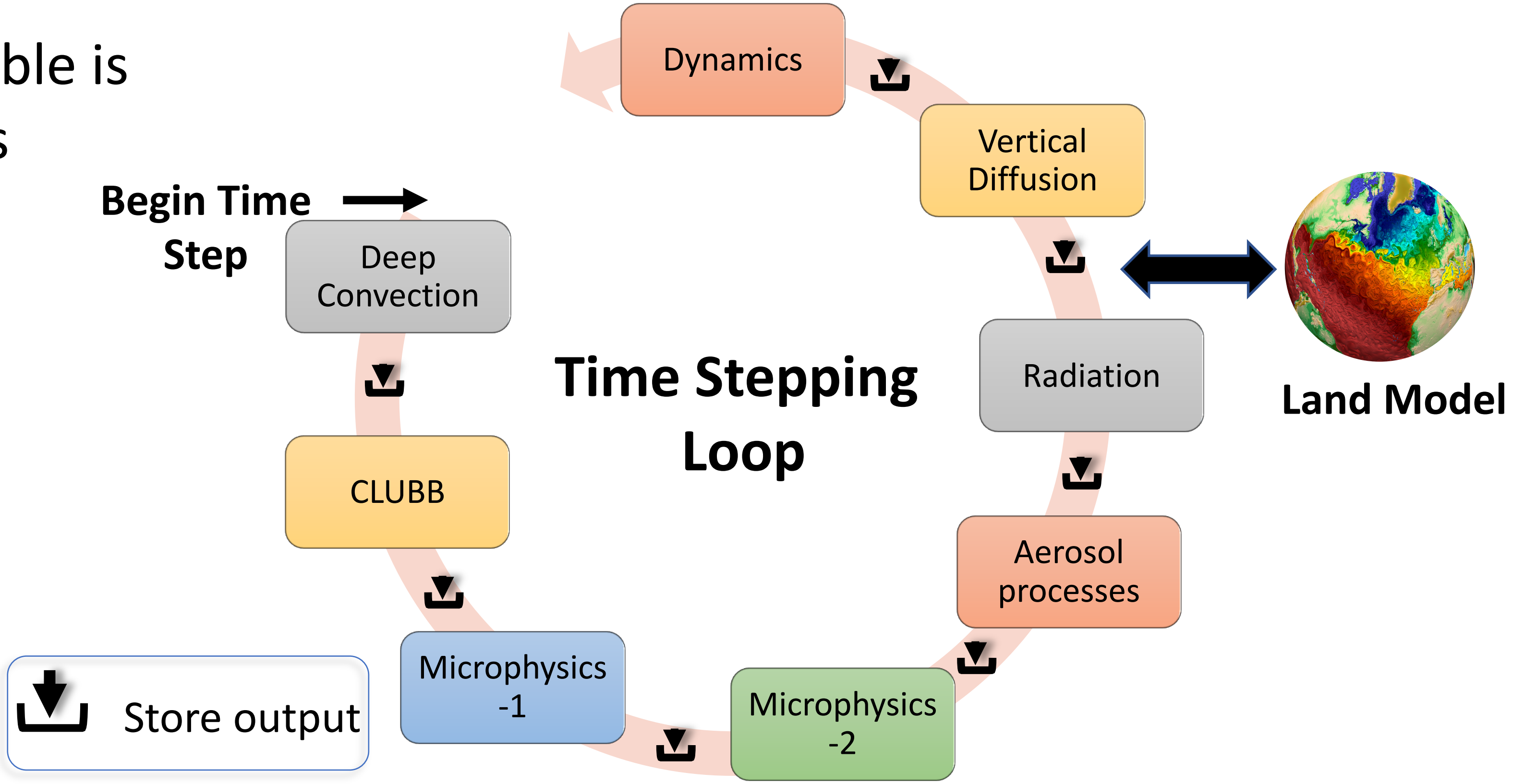
- Proposed Enhancements:
  - Vertical level and Constituent number



PERGRO Test Driven Tool

- Inspired from perturbation growth test
- Stores model output after every physical process
- Helps in tracking which state variable is affected by which physical process

```
pergro_test_active = .true.
```



- Proposed enhancements:
  - Ability to add/remove tracked state variables at runtime (Namelist)
  - Ability to track each sub-step of processes taking sub-steps (e.g. CLUBB and MG2)

Scenario – A Broken Restart Test

- Scenario: Modified code to add an enhancement but it broke the model's BFB restart capability

- First check all the obvious places
  - Carefully review new code modifications
  - Do we need new variables in the restart file?
  - Use a debugger/print statements to review the code

- Last resort – Isolate and understand the code causing non-BFB behavior

How to use these tools?

- Ways to expedite debugging:
  - Reproduce the problem:
    - On a coarsest possible resolution
    - With the least number of time steps (ideally one-time step)
    - Switch off compiler optimization
    - Use all compiler debugging options
  - Use your prior experience with E3SM

Pergro
Isolate the physical process causing model's state variables to differ

Script
Find model's state variable with max difference
Find latitude and longitude of the max difference

Phys Debug
Isolate line of code causing this difference

Common Test Cases

- Unexpected Non-BFB model results:
  - Broken model restart
  - Perceived BFB code modifications causing answers to change
  - Non-BFB results due to broken threading

- Wrong answers!
  - Value of a variable going out of range or beyond expectation
  - Bugs in the computing environment

Some Recent Debugging Exercises

- Compiler bug (Compy, Intel 19.0.3):

```
do k = 2, nz-1
   k_wp3 = 2*k - 1
   k_wp2 = 2*k

   rhs(k_wp3) = rhs(k_wp3) + invrs_dt
   rhs(k_wp2) = rhs(k_wp2) + invrs_dt
   rhs(k_wp2) = rhs(k_wp2) - 0.1D0
enddo
```

- MMF and phys_loadbalance

- Non-BFB radiation diagnostic code:
  - Processes invoked with different "states"
  - Identified missing processes

- MAM with added inactive mode
  - Identified several answer changing places in code
  - Found a bug in ways sea-salt indices are stored and used in the code