CCSM4 Software Engineering Improvements and Challenges

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New coupling architecture (CPL7)

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CPL7 Goals

User Friendly Component Parameterization
Model system permits each component to be developed and tested independently on even one processor (e.g. CAM/SCAM)

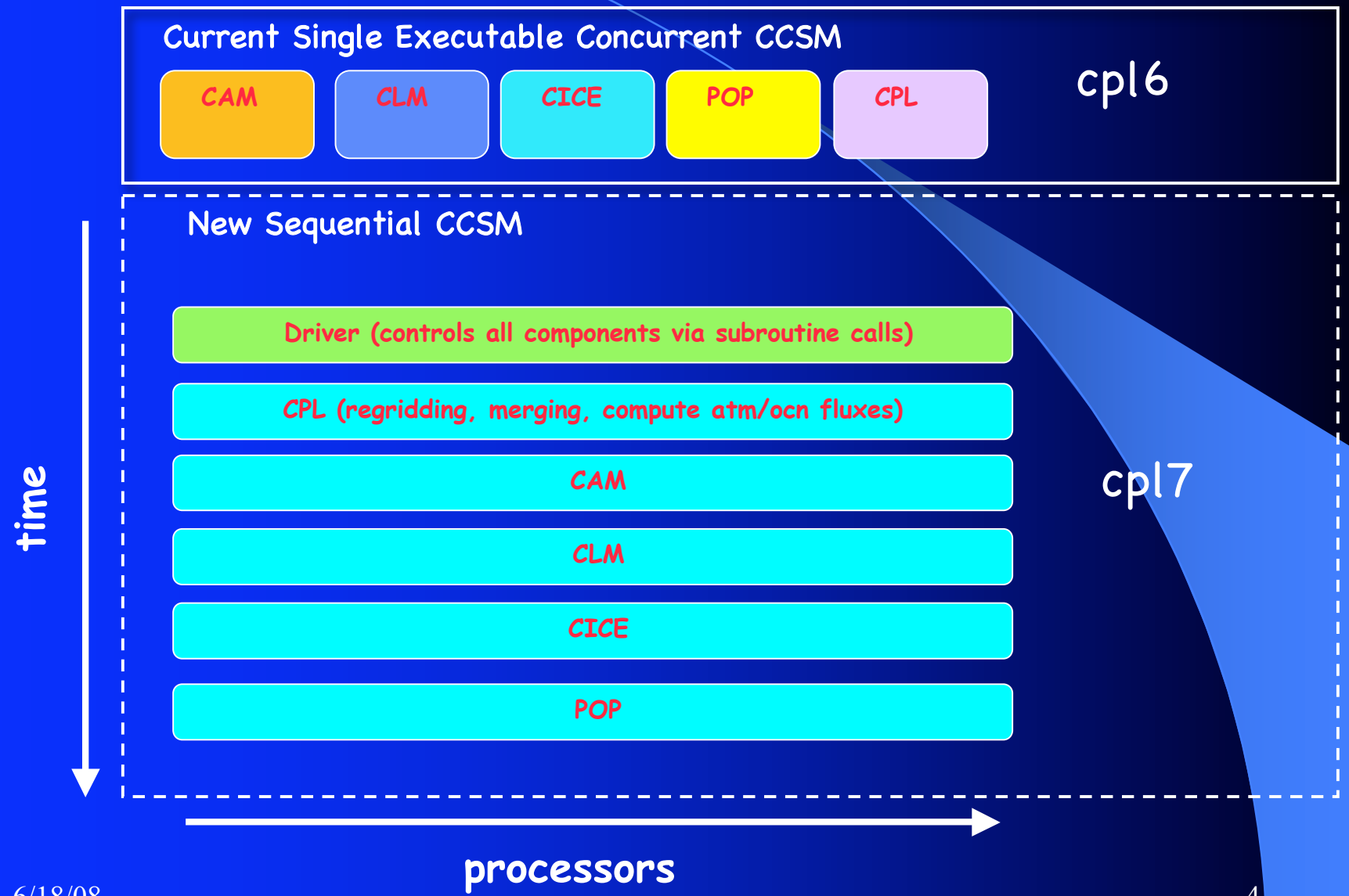
Scientific Consistency
One code base - "stand-alone" component code base is same as in fully coupled system

Single Interface for Component Communication
New fields exchanged between components should only be set in one place with one interface (e.g. dust)

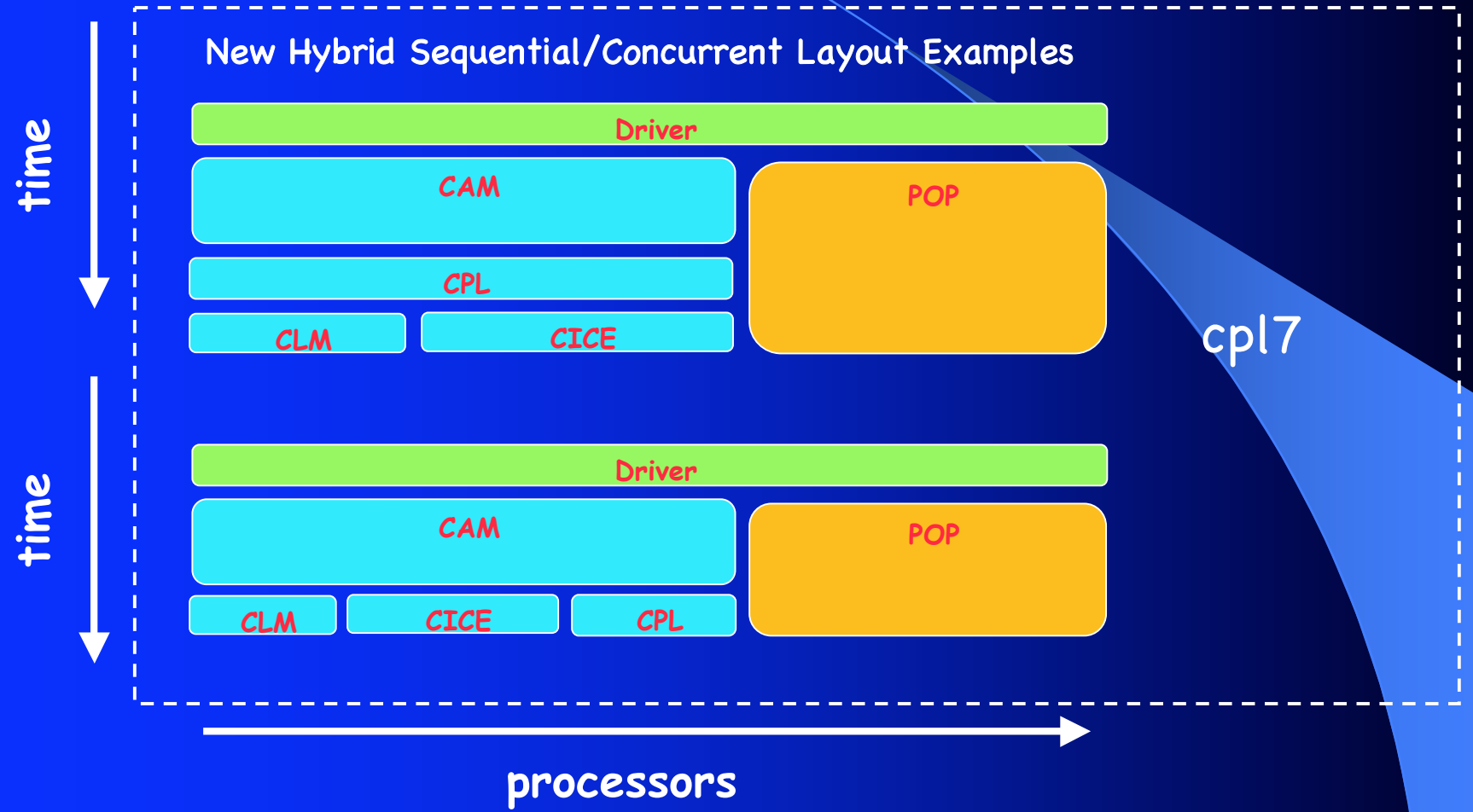
Extensibility
Design provides extensibility to add new components (e.g. land-ice)

Flexibility
Coupling architecture/components can run effectively at low resolution (e.g. paleo) and ultra-high resolution on thousands of processors.

CPL7 Design


Current Single Executable Concurrent CCSM
CAM
CLM
CICE
POP
CPL
cpl6
New Sequential CCSM
Driver (controls all components via subroutine calls)
CPL (regridding, merging, compute atm/ocn fluxes)
CAM
CLM
CICE
POP
cpl7
time
processors

CPL7 Design (cont)



CPL7 and scientific unification

- Historical stand-alone CAM is "gone"
  - ALL communication between CAM and surface components now goes through CPL7 driver
  - Only one ice model (replace CAM-CSIM with CICE) and hopefully only one slab ocean model (replace CAM-SOM with DOCN7/SOM)
  - ALL current CAM functionality has been preserved
    - SCAM, aqua-planet, ideal-physics, adiabatic
- Historical stand-alone CLM is "gone"
  - All communication between CLM and atmospheric component (DATM or CAM) now goes through CPL7 driver
  - Only one data atmosphere model (DATM used for CLM data model forcing).
- Capability for "end-to-end" development process in one CCSM tag
  - SCAM -> Prescribed SST/ICE-COV -> Fully active CAM/CLM/CICE/POP configuration

Status of CPL7

- Validation
  - Scientifically validated relative to CCSM/CPL6
  - Currently migrating all CCSM development work to CCSM/CPL7
- Scalability
  - Shown to have excellent scalability for both memory and performance
- Porting
  - Ported to NCAR IBM's, BlueGene (NCAR, BNL), XT4 (ORNL, NERSC), Linux clusters (LLNL, TACC)
  - Currently being used to carry out the LLNL Grand Challenge simulations on LLNL Atlas cluster
    - (.25° atmosphere/.1° ocean)
- Performance
  - Automated run-time performance/timing files produced for every batch submission

Current CPL7 Development Work

- Capability to have land/atm on different grid
  - Currently assumption of atmosphere and land on same grid is hard-wired into coupler
  - Enable CAM on cubed sphere (HOMME and GFDL cubed sphere dycores) to couple with CCSM surface components
  - Will maintain assumption of ocean and ice on same grid
- Incorporation of land ice component into CPL7
  - New component in driver
- Creation of CPL7 documentation
  - Reference Guide and Users guide
- ESMF Stage 2 implementation effort
  - Make components ESMF compliant
  - Create a new ESMF based cpl7 code base

CCSM4 CAM Development

- Finish implementation of new science
  - PBL scheme (final configuration currently unknown).
  - Morrison/Gettleman microphysics scheme.
  - New radiative transfer code (RRTMG)
    - Also new interface for specifying radiatively active species versus species only used for diagnostic calculations.
  - New code for cloud optical properties.
- Improve CAM-Chem code to provide more flexibility in selecting which aerosol species are prognostic and/or prescribed.
- Extend CAM configure/build-namelist to support new configurations and use cases.
- Carry out performance evaluation/optimization of new physics parameterizations.

CCSM4 CLM Development

- Implement improvements to datm7 offline data forcing.
- Finalize incorporation of urban model
  - Get global urban datasets into the model
  - Put in capability to use urban model with 15 soil layers
- Incorporate CN/Dynamic-Vegetation and crop model in development code base.
- Implement changes needed for Greenland ice-sheet model.
- Create new surface datasets with new lake, wetlands, urban, multi-elevation glacier and organic soil data.
- Add aerosol and dust coupling exchange with CAM (needed for SNICAR).

CCSM4 CICE Development

- Science
  - Validation of new science already in CICE code base (not on by default)
    - Delta-Eddington shortwave radiation with zenith-angle dependent albedo
    - Melt ponds.
  - Incorporation of new snow-aging parameterization
  - Finalize incorporation of CICE into CAM (as replacement to CAM-CSIM)
- Performance
  - Finish incorporation of OpenMP and carry out performance analysis
  - Implementation of weighted space-filling curves
  - Flush out current problems with padding in order to provide additional flexibility in domain decompositions.

CCSM4 POP2 Development

- Complete POP2 unification effort and migrate code base onto the POP2 trunk
- Integration of scientific developments into POP2 trunk
  - sub-mesoscale parameterization
  - overflow parameterization
  - horizontally-varying background vertical diffusivity / viscosity formulation
  - zenith angle dependent diurnal cycle of solar forcing
  - incremental remapping transport scheme
- Enable vectorization in POP2, participate in port of CCSM4 to CRIEPI SX8
- POP2 scripts
  - Redevelop POP2 input data handling
  - Develop pop2 script support for automated port validation

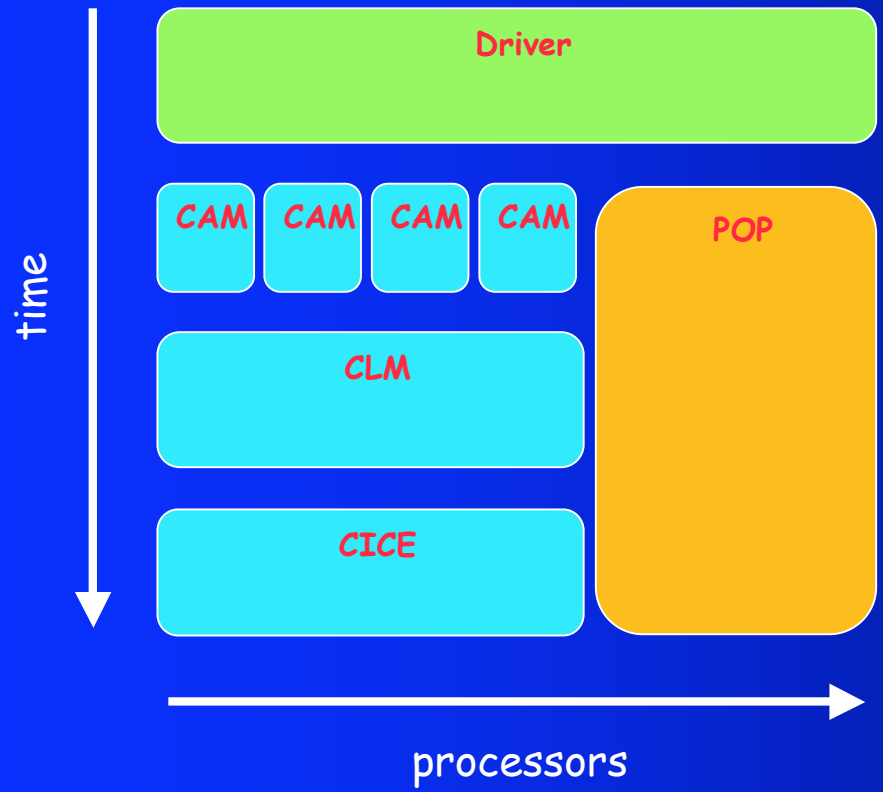
CCSM4 CSEG Development

- Creation of input data server
  - Will greatly simplify migration to new platform
- CCSM script upgrade
  - xml based
  - Expansion of CCSM test suite
  - Auto-documentation of variables- interact directly with CAM/CLM/CICE build-namelist
- Port to new platforms
  - Upgrade of porting process - more clear specification of validation process
  - Scaling and load balancing analysis on platforms
- Incorporation of PIO in all CCSM components
- Responsible for high resolution simulations

New Science - PetaApps

NSF PetaApps proposal funded - three-year research and development effort, aimed at enabling a broad climate science capability for petascale systems

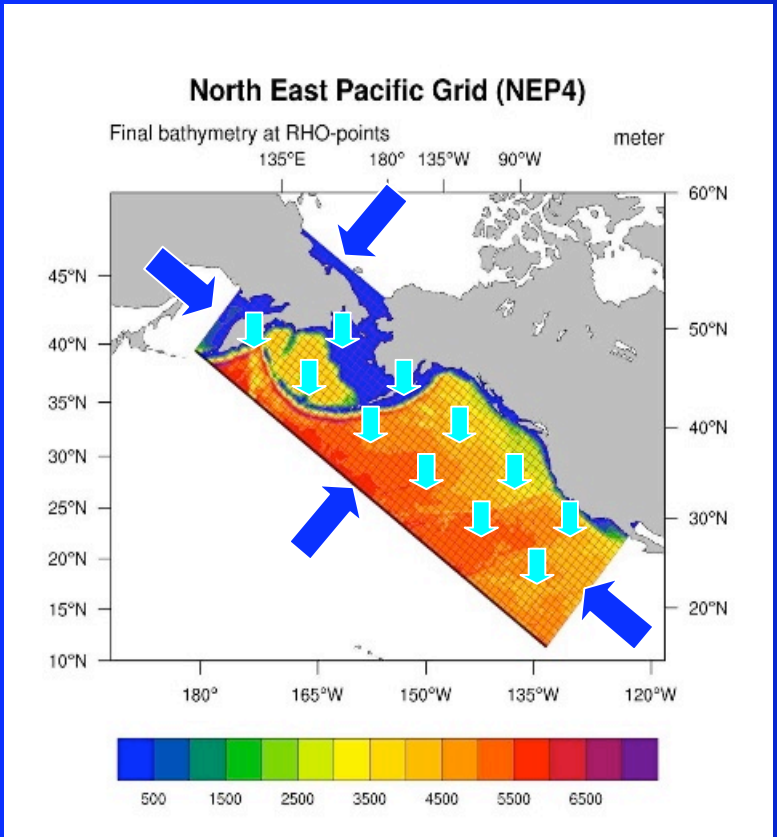
- Interactive ensembles using CCSM/CPL7
- Incorporate and examine use of PGAS language (Titanium) in CCSM



Interactive ensembles will be used to understand how oceanic and atmospheric weather noise impacts climate variability

Titanium will be used in the flux coupler to examine impact of PGAS language approach to performance and memory footprint

New Science – NRCM



Ocean Lateral Boundary Data

Atmospheric Surface Data

- Goal – nest regional models inside a global climate model to resolve biases by
  - Enhancing resolution in geographic areas of scientific interest without resolving the entire domain
  - Adding different physical parameterizations on different scales
- *First task:* nest ROMS in POP
  - created a composite OCN component containing POP/ROMS (based on CPL7 design)
  - merge POP/ROMS SST's as feedback to model
- *Next task:* nest WRF in CAM