Coupling Approaches for Next Generation Architectures (CANGA)

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CANGA Goals

• Highly performant, accurate and robust coupling strategies for a new E3SM
• PIGLET: Prototype Integration of Global models using Legion Execution of Tasks
  • Replace hub/spoke, monolithic components
  • Asynchronous Many-Task Model
  • Exposes more parallelism
  • Better load balancing
  • Fault tolerance
  • Manage complexity
  • Enable process coupling at proper time, spatial scales
CANGA Goals

• Upgrade coupling algorithms
  • Remapping Online-Offline (ROO)
    • Non-convex cells
    • On-line adaptive remapping
    • Vector and property-preserving
    • Meshfree (agnostic to staggering location)
    • Remap test suite
  
• Time InteGration for Greater E3SM Robustness (TIGGER)
  • Replace ad-hoc time-lagging and instability
  • Address multiple space, timescales
  • Integrate into task-based coupler

• Applications, mini-apps
  • Simpler coupled systems to analyze, evaluate
Task Parallelism with Legion and FleCSI

- Legion
  - Stanford/LANL/Nvidia
  - Logical regions intersect field/index space
  - Fast runtime analyzes dependencies (DAG) and schedules tasks
- FleCSI: C++ framework designed for multi-physics apps
  - Run-time abstraction layer (Legion, Charm++, HPX, MPI)
  - Control, execution and data models
Task-parallel implementation approach

- **Top-down**
  - Reproduce current coupling
  - Currently have Regent prototype
    - Converting to FleCSI
  - Not enough parallelism
- **Bottom-up**
  - Begin to create task-based components
  - Ocean/ice (MPAS)
    - Large component – prototype interfaces
  - Land Model
    - Ideal component w/ many tasks that have high space and time heterogeneity
  - Extract in-situ analysis (RAPIDS)
    - Lagrangian particle tracking
Field remapping

- Current coupler
  - Conservative, bilinear, others
  - Static, linear, convex cells
- CANGA-ROO
  - Irregular meshes (offline, static)
  - Adaptive on-line
    - Changing mesh/boundary, adjust order
  - Meshless
    - Support field staggering
  - Vector fields
  - Property-preserving
    - Constrained optimization
  - Test framework
    - Analytic fields derived from observation
    - Spherical harmonic truncated expansion

Optimization+meshfree remap: treating DoF as scattered data allows to circumvent complications of non-coincident interfaces.
Time integration of coupled systems

• Current coupling
  • Explicit integration based on flux/field exchange
  • Time-lagged or time-averaged fields to enable concurrent execution and ease of interface
  • Effectively a sub-cycling approach: no reason why it shouldn’t [not] introduce instabilities

• New approaches to advance integrated system
  • Consistent schemes with no/minimal iteration
  • Example: Lagrangian multiplier/dual Schur complement approaches
    • Still solve independently in each subdomain, estimates of flux/BC info

• Shift to multiple process timescales in task-parallel system
Simpler model hierarchy

- Capture enough complexity but no more
  - Perform stability analysis of integrated coupled system
  - Explore impact/feasibility of new time integration algorithms

- Hierarchy
  - Coupled transport (advection-diffusion) on two domains
  - Linearized Navier-Stokes
  - Q-GCM: quasi-geostrophic
  - All include field remapping

- Simple python coupler
  - Replaced by task-based coupler
Task–based Models
P. Jones (LANL)

Coupler Prototype
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Land Model
E. Coon, S. Painter (ORNL)

Ocean, Ice
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Legion Support
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In Situ analysis
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Remapping (ROO)
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TempestRemap Extensions
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Property-preserving and meshless
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Adaptive Remap
X. Jiao, Stony Brook

Applications and reduced complexity models
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Reduced complexity models
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Time integration
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Time Integration
H. Zhang (ANL)

ASC funded

BER funded

Time Integration and Applications
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Performant accurate, robust AMT coupled system

Ocean, Ice
I. Demeshko, PD, P. Jones (LANL)

Land Model
E. Coon, S. Painter (ORNL)

Time Integration
H. Zhang (ANL)
Challenges, potential SciDAC links

• Task-parallel strategies
  • Many packages focused more on standard domain partitioning
  • Everyone wants control of data layout
  • Still need to optimize for node-level memory, core features (platform ready)
  • In-situ analysis, I/O as additional task parallelism

• Remapping
  • Optimized mesh and meshless tools: searching, geometry, partitioning/ordering
  • Property preservation, higher-order

• Time integration
  • Algorithms, approaches for less tightly coupled systems and with minimal iteration