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Albany Users Meeting

# AERAS: A NEXT GENERATION ATMOSPHERE MODEL

Sandia National Laboratories

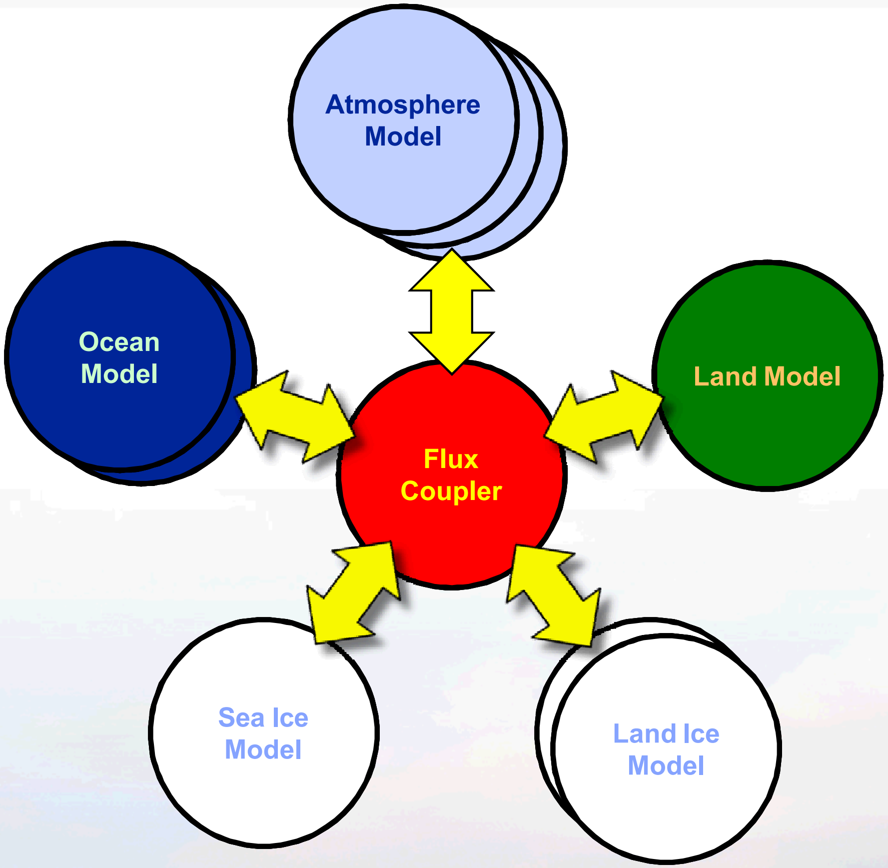
# Outline

- Aeras Project Goals and Background
- Modeling Approach
- Current Status
- Required Capabilities

# Aeras Project Goals

- **Next Generation Atmosphere Model LDRD**
- **Proposal:**
  - Demonstrate leading edge Sandia technologies for developing geophysical flow models via Albany
  - Stress capabilities not found in existing climate model components
    - Performance portability
    - Embedded UQ
    - Support multiple discretizations
    - Support hydrostatic and nonhydrostatic formulations
  - Strategically aimed at Office of Science and their move away from the Community Earth System Model (CESM)
- **Team**
  - Bill Spotz (PI), Andy Salinger, Mark Taylor, James Overfelt, Steve Bova, Irina Kalashnikova, Erika Roesler, Tom Smith

# Background: High-Level View of CESM

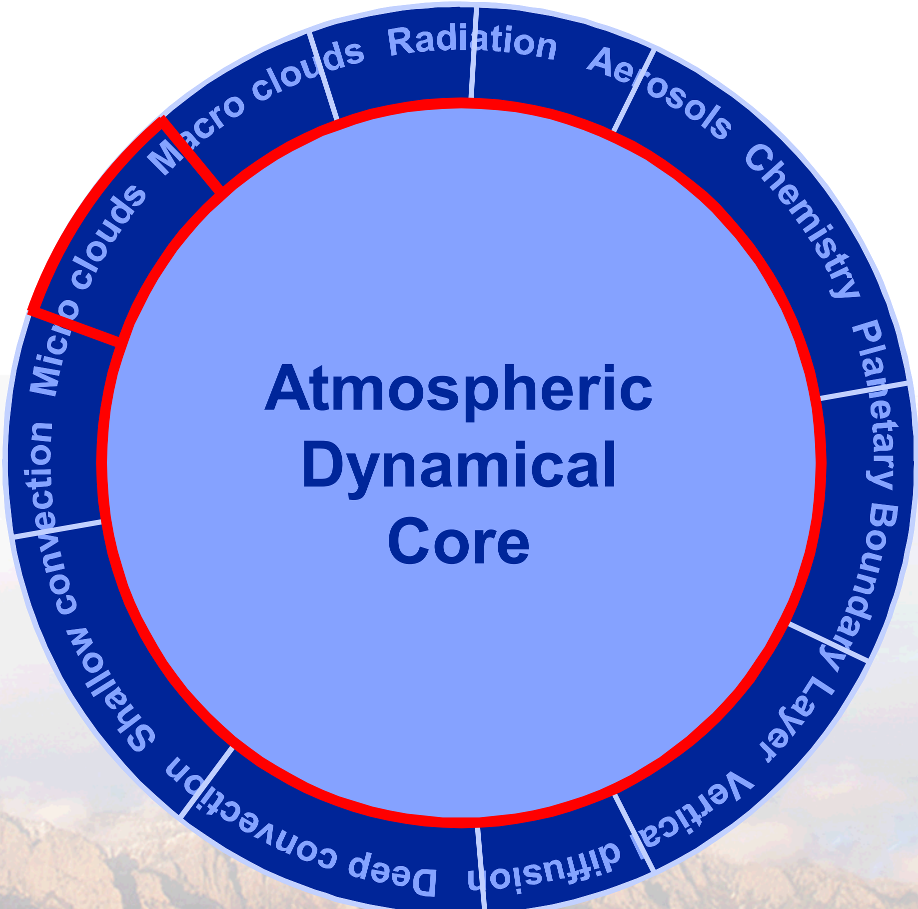



- **Six components**
  - Atmosphere model
  - Ocean model
  - Sea ice model
  - Land ice model
  - Land model
  - Flux coupler
- **Modularity**
  - Plug-and-play design has allowed CAM-SE (Community Atmosphere Model – Spectral Elements, with significant Sandia effort) to become default atmosphere model

# Background: Community Atmosphere Models

$$\frac{\partial \mathbf{u}}{\partial t} + (\zeta + f)\hat{\mathbf{k}} \times \mathbf{u} + \nabla\left(\frac{1}{2}u^2 + \phi\right) + \dot{\eta}\frac{\partial \mathbf{u}}{\partial \eta} + \frac{RT_v}{p}\nabla p = 0$$

- **Dynamical core**
  - Conservation laws (Euler in spherical, rotational inertial frame)
  - Sources and sinks
- **Physics parameterizations, typically sub-grid scale and empirical**
  - Convection (deep and shallow)
  - Clouds (different scales)
  - Radiation
  - Aerosols
  - Chemistry
  - Planetary boundary layer
  - Vertical diffusion
  - Gravity wave drag
  - Etc….



# Approach

- **Atmosphere models have some very specific features that result in somewhat unique numerical approximations**
  - A spherical shell domain (no [horizontal] boundaries)
  - A very small vertical (radial) dimension: horizontal + vertical operators
    - Strongly tied to hydrostatic pressure ➔ mathematically simple BC
  - Hydrostatic assumptions that simplify calculations (on “coarse” grids)
  - A separation of dynamical core and physics modules
    - Physics: column based and on-processor
  - A physical regime conducive to explicit time-stepping
    - Spectral transform method (no mass matrix, semi-implicit)
    - Spectral element method (diagonal mass matrix)
- **Aeras:**
  - Finite element and spectral element
  - Implicit and explicit
  - 2D curvilinear elements on manifolds
  - Hybrid vertical coordinate system(s)
  - Continuous and discontinuous (CG, DG and hybrid)

# Status

- **Elements on manifolds**
  - 3D coordinates, but 2D parametric space
  - Shell-like elements available to Albany
  - For Aeras, projection to a mathematically spherical surface
- **Shallow water equations**
  - Implemented on the sphere
  - Linear elements
  - Implicit
  - Test Case 1
- **X-Z equations**
  - Scalar advection
  - Linear elements
  - Implicit

# Required Capabilities

- **High order elements**
  - Enrichment of quadrilateral elements
  - New STK templates
  - Need STK "2"
- **Explicit (Gauss Lobatto element integration)**
  - Some assumptions about implicit formulation within Albany
  - Efficiency issues
- **Performance portability**
  - This applies to all Albany projects, not just Aeras…
- **Mixed order elements**
- **Discontinuous Galerkin**
- **Sensitivities and DOFs issue**
  - Column-based physics reduces the coupling between DOFs
  - Will this lead to performance issues?