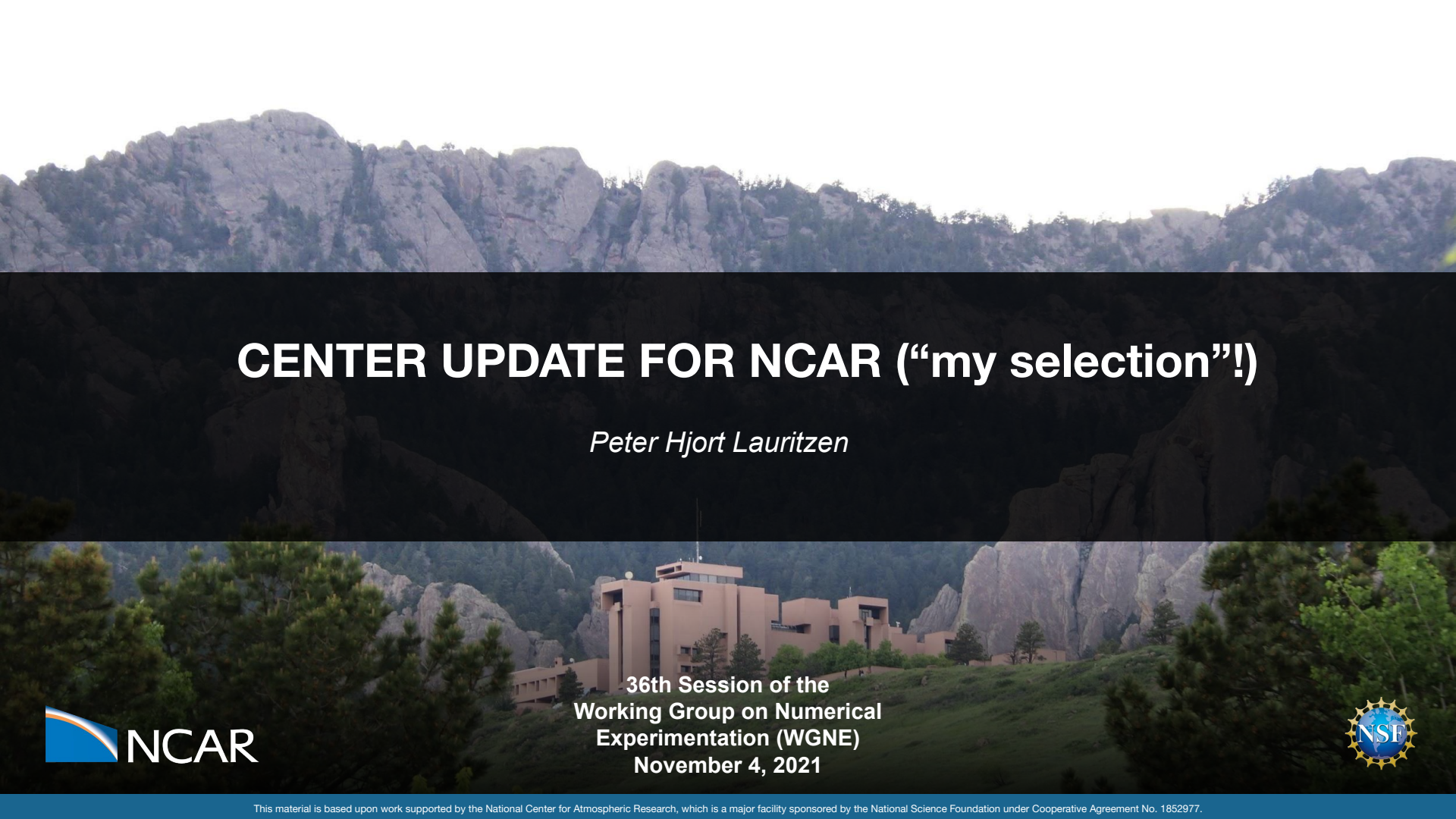


CENTER UPDATE FOR NCAR (“my selection”!)

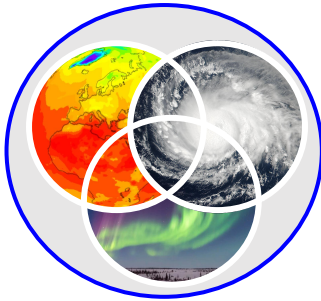
Peter Hjort Lauritzen

36th Session of the
Working Group on Numerical
Experimentation (WGNE)
November 4, 2021

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

SIMA

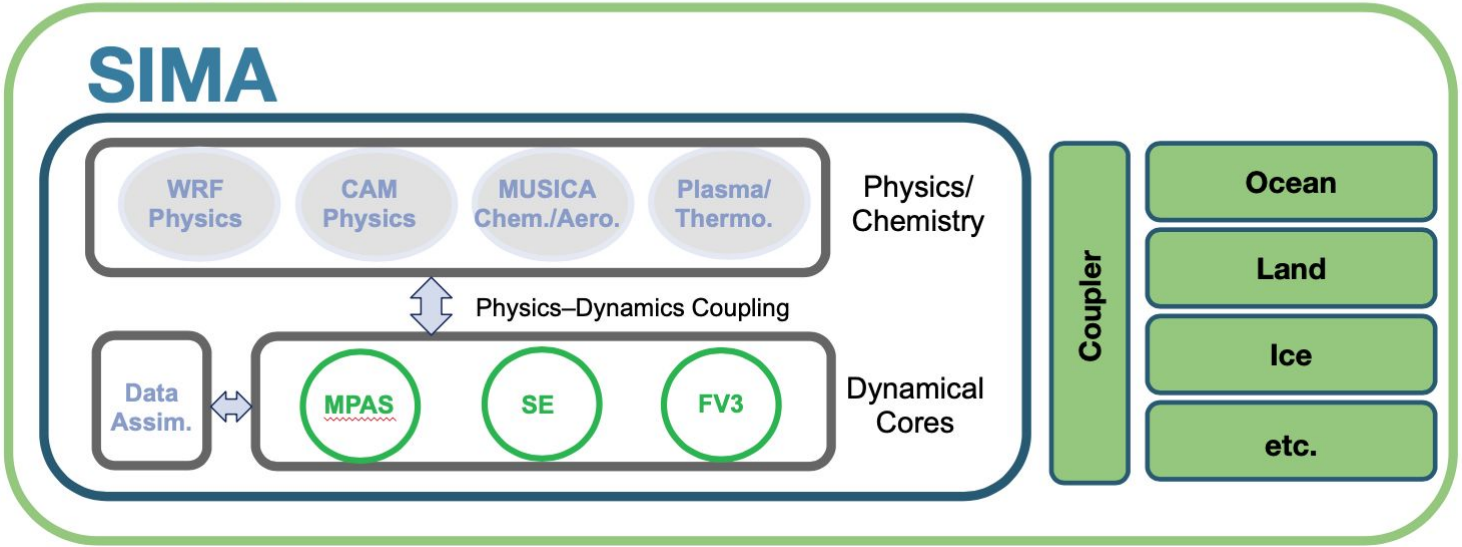
(System for Integrated Modeling of the Atmosphere)



SIMA is an effort to unify **community** atmospheric modeling across weather, climate, chemistry, and geospace

CESM (=Community Earth System Model)

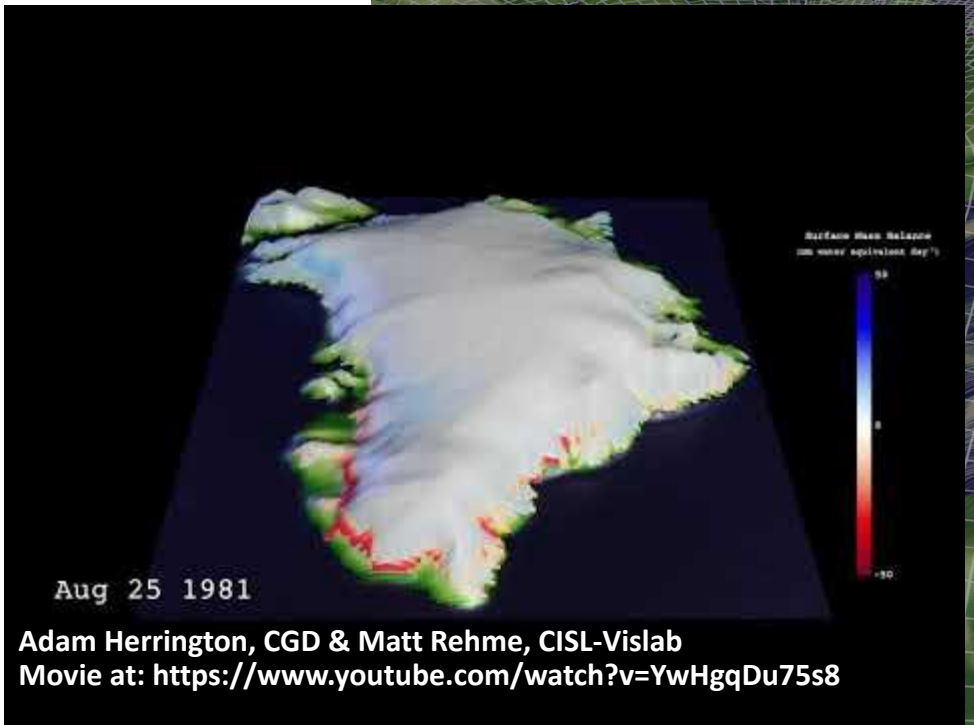
Atmosphere component of CESM is CAM (Community Atmosphere Model)



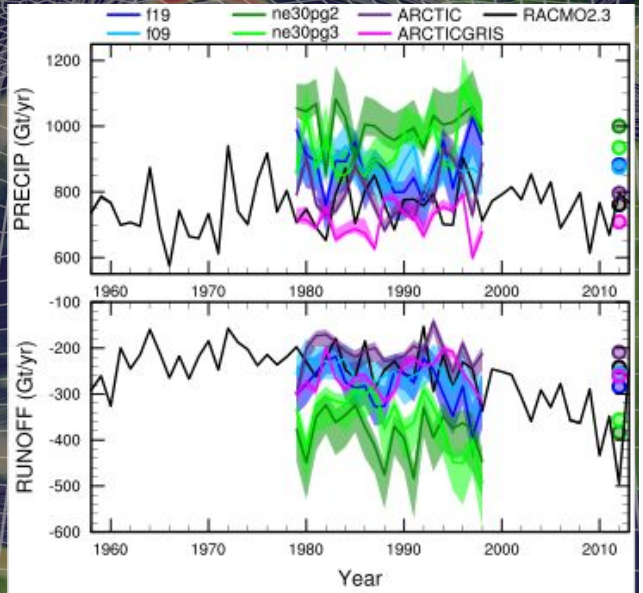
http://sima.ucar.edu

Example frontier SIMA Application: Coupled regional climate in global CESM (e.g. polar)

A lot of effort has been put in to developing community tools for setting up custom regional refined simulations!



Adam Herrington, CGD & Matt Rehme, CISL-Vislab
Movie at: https://www.youtube.com/watch?v=YwHgqDu75s8



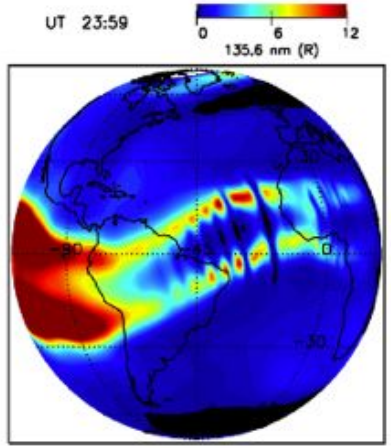
Example frontier SIMA Application: Geospace

(WACCM-SE-CSLAM at ~25km, ~600km model top)

Coupling to dynamic magnetohydrodynamic model GAMERA
(provides electric potential and energetic particle information which is efficiently mapped to model grid)

Species dependent thermodynamics

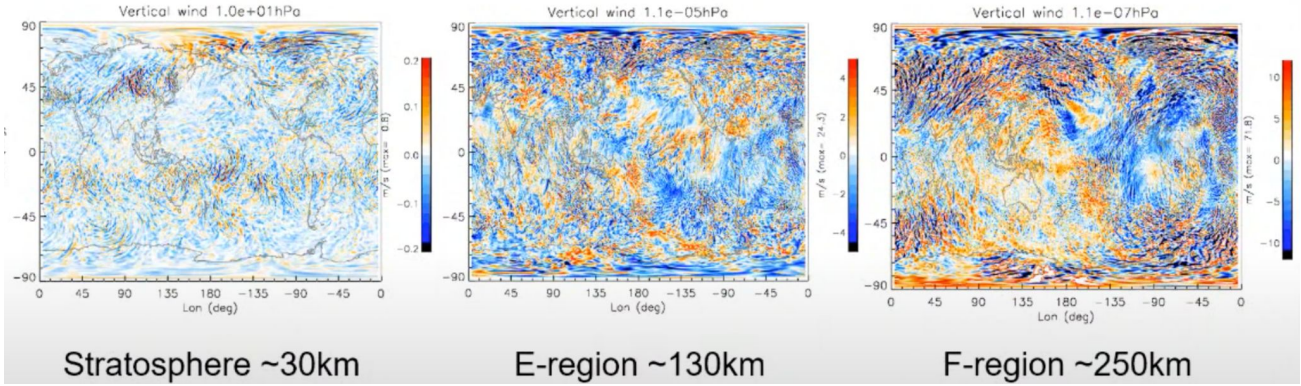
Molecular viscosity and thermal conductivity in spectral-element dynamical core



WACCM-X Coupled to plasmasphere model: Waves generate ionosphere bubbles (first in a global model)

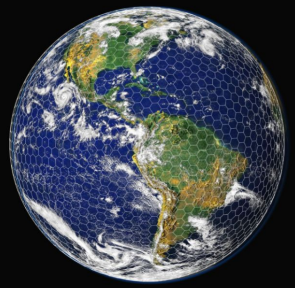
Vertical winds: WACCM-X (NE120/L273)

120 elements ~ 25km resolution, 273 vertical levels ~ 1/10 scale height



Example frontier SIMA Application: Ultra-high res

EarthWorks



EarthWorks is a five-year project to develop a global coupled model, based on the CESM, that uses the same *~4 km global grid* for the atmosphere, ocean, and land surface.

The model will be used to study both weather and climate.

EarthWorks is based on the CESM infrastructure, but it is not a CESM project.


CSU


CSU


MMM


CGD


CISL

Model for Prediction Across Scales dynamical core (MPAS): Consistent coupling with the CAM physics package

$$\theta_m, \vec{v}, \rho_k^{(d)}, m^{(\ell)} \rightarrow T, \vec{v}, \Delta p, q^{(\ell)}$$

2.2 MPAS prognostic variables

MPAS prognostic variables are (omitting horizontal index):

- $\theta_k^{(m)}$: layer mean modified potential temperature
- $\rho_k^{(d)}$: mid-level dry density
- $z_{k+1/2}$: interface height; layer thickness is $\Delta z_k = z_{k-1/2} - z_{k+1/2}$
- $m_k^{(\ell)}$: layer mean dry mixing ratio of constituent ℓ
- velocity components at mid-level

where k is level index. It is furthermore assumed that the mid-level is located at

$$z_k \equiv \frac{1}{2}\left(z_{k+1/2} + z_{k-1/2}\right). \quad (1)$$

The modified potential temperature in MPAS is defined as

$$\theta_k^{(m)} = \left[1 + \frac{1}{\epsilon} m_k^{(wv)}\right] \theta_k, \text{ where } \epsilon \equiv \frac{R^{(d)}}{R^{(wv)}} \quad (2)$$

(Skamarock et al., 2012, see equation 2) where

$$\theta_k \equiv T_k \left(\frac{P_0}{p_k}\right)^{\kappa}, \quad (3)$$

2.1 CAM physics state variables

Not including state variables in specific parameterization, the CAM physics prognostic state variables are (omitting horizontal index):

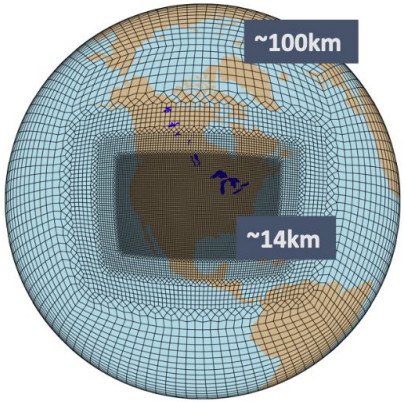
- T_k: mid-level temperature
- Δp_k: pressure level thickness
- $q_k^{(\ell)}$: layer mean specific/moist mixing ratio of constituent ℓ
- velocity components at mid-level

where k is level index.

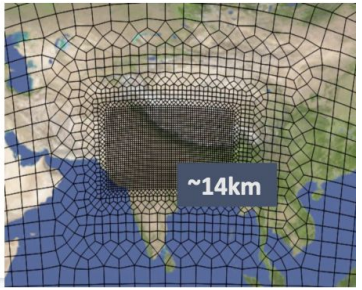
Example frontier SIMA Application: Chemistry

MUSICA V0 Applications

- MUSICA-V0 = CAM-chem, Spectral Element with regional refinement
- Default grid: ne30x8 over CONUS (14km over US, 1-deg rest of globe)
- Other grids: Asia, India, South Korea, Africa

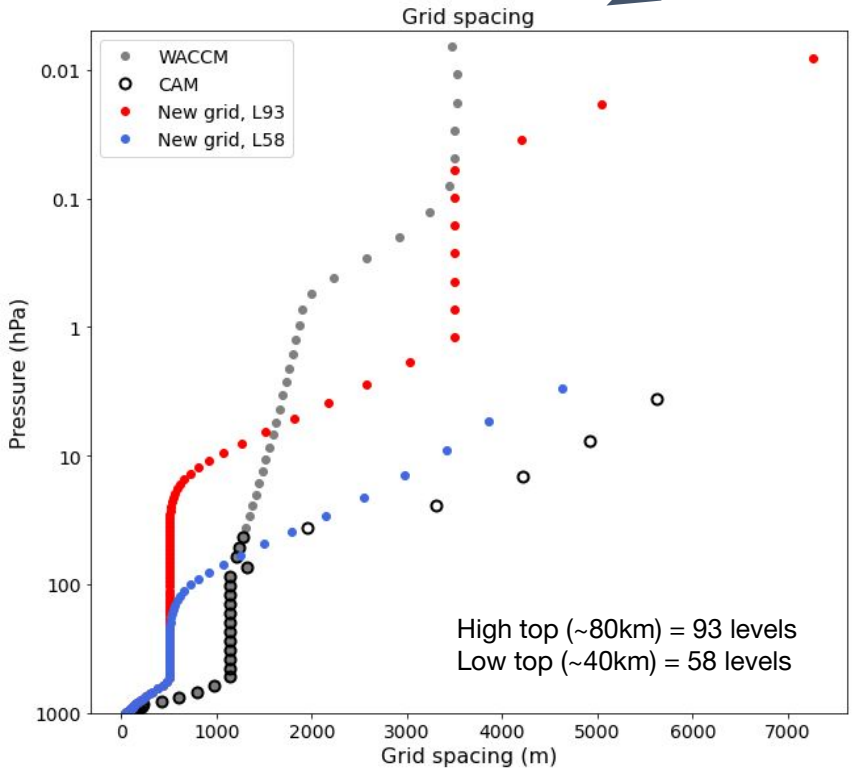


- Ozone air quality and chemical complexity (R. Schwantes)
- PM2.5 and health effects (F. Lacey)
- Fire emissions (W. Tang)
- Asian monsoon outflow ACCLIP campaign (R. Smith, J. Zhang)
- India air quality (B. Roozitalab)
- Effect of biomass burning in the Gulf of Guinea (O. Ajoku)
- Set of CONUS simulations for community analysis (S. Tilmes)



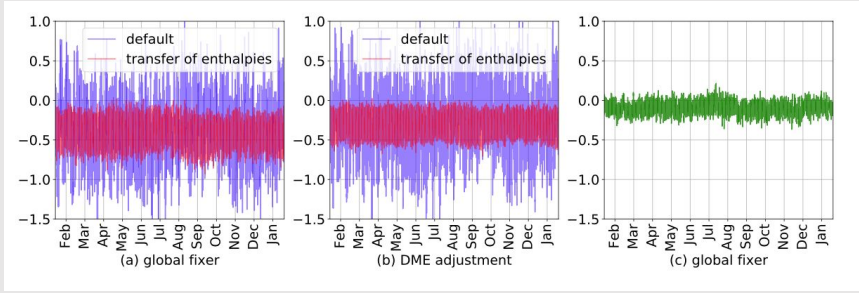
Next generation CAM

(CAM7 in CESM3)



List of CAM developments underway

- Vertical grid/resolution (higher top, more levels)
- Dynamical core development (SE,MPAS,FV3)
- CCPP infrastructure
- Physics re-ordering
- Enthalpy fluxes to other components (MOM6)
- CPT: Implementation of CLUBB-EDMF
- CPT: Prognostic momentum fluxes in CLUBB
- CPT: Land surface heterogeneity interacting with atmosphere
- Other: Microphysics (PUMAS), Radiation (RRTMGP), Convection (ZM2)



$$\frac{\partial}{\partial t}\iiint \rho^{(d)}\Big\{K+\Phi_s+c_p^{(d)}T+\sum_{\ell\in\mathcal{L}_{H_2O}} m^{(\ell)}\left[K+\Phi_s+c_p^{(\ell)}\left(T-T_{00}\right)+h_{00}^{(ice)}\right] + m^{(wv)}L_{s,00}+m^{(liq)}L_{f,00}\Big\}dA\,dz$$

$$=\iint\Big\{\sum_{\ell\in\mathcal{L}_{H_2O}} F_{net}^{(\ell)}\left[\widetilde{K}_s+\Phi_s+c_p^{(\ell)}\left(\widetilde{T}_s-T_{00}\right)+h_{00}^{(ice)}\right]+F_{net}^{(wv)}L_{s,00}+F_{net}^{(liq)}L_{f,00}+F_{net}^{(turb,rad)}\Big\}dA.$$

Lauritzen et al. (in prep): **Reconciling and improving formulations for thermodynamics and conservation principles in Earth System Models**